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The impact of poultry manure on water quality using tile drained field plots and lysimeters

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The impact of poultry manure on water quality using tile drained field plots and lysimeters

by

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Signatures have been redacted for privacy

DEDICATION

To Jesus Christ, my mom and brother, and Dr. Kanwar.

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ABSTRACT

This research is the continuation of a six-year project, started in 1998 by Adion Chinkuyu, to study the effects of poultry manure on subsurface tile water quality and runoff water quality; and this thesis presents the combined data of Chinkuyu's research (1998-2000) and data collected by myself and others (2001-2003) to conclude the overall outcome of the six year study.

The six-year study was conducted to determine the effects of four experimental treatments [168 kg N/ha from poultry manure, 168 kg N/ha from urea-ammonium nitrate (UAN), 336 kg N/ha from poultry manure, and 0 kg N/ha (control treatment)] on corn and soybean yields, grain quality, corn stalk N, soil NO_3-N, soil PO_4-P, subsurface tile drainage and runoff water quality, and bacteria concentrations in subsurface drainage and runoff waters. Eleven field plots were planted to a corn-soybean rotation while six lysimeters were planted to continuous corn. To this day, only 5 complete years of data have been collected. Conclusions made thus far indicate that the 168 kg N/ha from poultry manure treatment is the better choice in applying nutrients to fields because of high yields, which were significantly higher than the 168 kg N/ha application of UAN and similar to the higher rate 336 kg N/ha from poultry manure treatment. In addition, the 168 kg N/ha from poultry manure treatment resulted in reduced levels of soil NO_3-N levels compared to 168 kg N/ha UAN treatment and lower soil PO_4-P trends compared to the 336 kg N/ha poultry manure treatment. Also, the 168 kg N/ha application from poultry manure resulted in reduced NO_3-N losses in subsurface drainage water as compared to the 168 kg N/ha UAN and 336 kg N/ha poultry manure treatments. The effects of all treatments on bacteria concentrations in subsurface drainage water were not significantly different from each other. As long as the poultry manure is

applied at reasonable nitrogen rates (of 168 kg N/ha), it makes a good soil amendment, gives better crop yields, and reduced NO_3-N concentrations in subsurface drain water compared to 168 kg N/ha from UAN and 336 kg N/ha from poultry manure.

CHAPTER 1: GENERAL INTRODUCTION

Introduction

Iowa's egg industry continues to grow each year. In 2001 Iowa became the number one egg producing state in the US, producing 8.69 billion eggs (USDA-NASS, 2002). In 2002, Iowa broke its record producing 9.91 billion eggs, thus maintaining its position as number one egg producing state for 2002 (USDA-NASS, 2003) (Table 1.1). In order for Iowa to continue producing such a high number of eggs, an average of 675 million pounds of feed per year would be required leading to the generation of some 817 million pounds of manure per year (Beyer, 2002; Schwantz, 1979; SCS, 1992; USDA-NASS, 2003) (This does not include waste from other chicken types such as broilers etc.) (Table 1.2). With so much waste being generated every year brings the need to find ways of turning that waste into something that is wanted. The most common way of utilizing manure waste is to apply it on fields to help add valuable nutrients for growing crops. Unfortunately, the amount of nutrients present in the manure typically is not present in same ratios as are needed by the crops to be grown. This can result in the over application of some nutrients while attempting to meet all nutrients requirements for crops leading to water quality problems from nutrient contamination through runoff and subsurface flow. To help combat these water quality problems, policies are needed to help regulate how much manure can be applied to fields on the basis of nitrogen requirements of crops to be grown. Nitrogen was chosen since more nitrogen will be need than the other nutrients, which allows for more utilization of manures, plus the health effects of nitrogen in drinking water were known and being regulated. Unfortunately, the amount of phosphorus that is added to fields based on the nitrogen rates is higher than what the crops need. Over time the excess

Table 1.1. Iowa's egg industry statistics for the years 1998-2002.

Year	Rank	No. of eggs produced	Average No. of Layers	Rate of Egg Laying Per Year Per Hen
1998	4th	5,969,000,000	23,044,000	259
1999	2nd	6,754,000,000	25,623,000	264
2000	2nd	7,554,000,000	28,098,000	269
2001	1st	8,691,000,000	32,591,000	267
2002	1st	9,910,000,000	36,980,000	268

*Information from the USDA National Agricultural Statistics Service (USDA-NASS, 2003, 2002, 2001, 2000, 1999)

Table 1.2. Calculations for feed use and waste production by laying hens.

Assumptions:

1. Iowa has an average of 36,980,000 layer hens in 2002 (NASS, 2002)
   Each layer hen produce 268 eggs per year
   Iowa produced 9,910,000,000 eggs in 2002

2. Layer hen cycle = 12 months (Beyer, 2002)

3. 0.5 lb of 15% protein feed given per 10 hens per day (Schwantz, 1979)

4. 60.5 lb manure/1000 layer hens is produced each day having a volume of 0.93 ft^3 manure/1000 hens/day (value is manure as excreted with moisture being 75% of total wt) (SCS, 1992)

Amount of feed needed to supply Iowa layer hens in a year 2002.

$$36{,}980{,}000 \text{ hens} * \frac{0.5 \text{ lb feed}}{10 \text{ hens} * \text{day}} * \frac{365 \text{ days}}{1 \text{ year}} = \mathbf{\frac{674{,}885{,}000 \text{ lb feed}}{\text{year}}}$$

Amount of manure generated by Iowa layer hens in 2002.

$$36{,}980{,}000 \text{ hens} * \frac{60.5 \text{ lb manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{816{,}610{,}850 \text{ lb manure}}{\text{year}} = \mathbf{\frac{816{,}611{,}000 \text{ lb manure}}{\text{year}}}$$

$$36{,}980{,}000 \text{ hens} * \frac{0.93 \text{ ft}^3 \text{ manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{12{,}552.861 \text{ ft}^3 \text{ manure}}{\text{year}} = \mathbf{\frac{12{,}553{,}000 \text{ ft}^3 \text{ manure}}{\text{year}}}$$

phosphorus builds up in the soil and is washed off fields in runoff and in subsurface tile flow. This can lead to other water quality problems, which became known much later. Thus, other methods of nutrient management were employed in order to reduce the high phosphorus levels that had become prevalent in soils that were being overly applied and to prevent phosphorus loss from fields.

Thesis Organization

This thesis is broken down into six main parts: a general introduction and literature review; a first paper on the effects of poultry manure on crop yields, grain quality, and corn stalk N; a second paper on the effects of poultry manure on water quality with respect to NO_3-N concentrations and losses and PO_4-P concentrations and losses; a third paper on the effects of poultry manure on soil NO_3-N and PO_4-P; a four paper on the effects of poultry manure on water quality with respect to bacteria concentrations; and lastly a section for general conclusions based on all four papers. In addition, there are two appendixes for each chapter's notes, and more detailed descriptions of testing procedures not included in the main papers. Also, each main chapter and appendix contains its own list of references.

Literature Review

Nutrients needed by plants

There are thirteen mineral nutrients needed by plants for healthy growth. These thirteen nutrients are divided into two groups based on the general amounts needed by plants. Those nutrients needed in large amounts include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), while those nutrients needed in trace amounts included boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo), and zinc (Zn). Of the nutrients needed in large amounts, nitrogen, phosphorus, and potassium are needed to such an extent that amendments (in the form of manures and fertilizers) are usually added to the soil to replenish what has been utilized during previous growing seasons (Gaines, 1977).

Ratio of nitrogen/phosphorus/potassium in poultry manure/fertilizers

While applying manure to the soil helps to replenish valuable nutrients, the ratio of these nutrients needed by the plants tends to be different than that replenished by the manure being applied. Additionally, the ratio needed of any single plant type tends to differ from all others (SCS, 1992) (Table 1.3). Thus, it is important to carefully consider how much manure should be applied so that the crops to be grown will have enough nitrogen, phosphorus and potassium for growth. Generally, the manure is tested for these nutrients so that enough will be applied. On the other hand, if manure is applied at rates just to utilize as much manure as possible, it can be worse than under applying the nutrients. As Chinkuyu et al., 2002 previously researched, too much of a particular nutrient can cause problems to plants, and the excess nutrients tend to be flushed out of the soil and into water systems impacting the health and environment of those who utilize those water systems (Edwards and Daniel, 1992; Fulhage, 1993; Giddens and Barnett, 1980). A closer look at each nutrient will help to better understand the role of each.

Table 1.3 Ratio of N:P:K required for corn and soybeans, and that available in laying hen manure.

Nutrient	Corn	Soybeans	Laying Hen (as excreted)
N	5.7	9.9	2.7
P	1.0	1.0	1.0
K	3.6	3.4	1.1

*Information from Soil Conservation Service, Agricultural Waste Management Field Handbook, 1992, Tables (4-14) and (6-6).

Nitrogen

Nitrogen Use and Loss

Nitrogen is needed during the vegetative and reproductive stages of a plant's growth for components like strong stems and the production of chlorophyll (Evans, 1993; Gaines, 1977). When manures are applied to fields, the nitrogen in them may be in both organic and inorganic forms. Plants cannot absorb the organic forms of nitrogen; but, once the manure is incorporated into the soil, the nitrogen undergoes mineralization (the process of breaking down organic materials into inorganic materials). Both organic and inorganic forms are converted to nitrate (NO_3), an inorganic nitrogen form. Plants can absorb the nitrate as well as ammonium (NH_4), which also is an inorganic nitrogen form. Ammonium is both initially present in manure before it is applied as well as being an intermediate product in mineralization (Zhang et al., No Date).

Nitrogen can be loss from the soil through leaching and in runoff water because nitrate and ammonium are water-soluble. When a rain event occurs, the nitrate, which is in solution in the soil, becomes incorporated in the rain water and is carried from the soil surface layer by the rainwater as it runs off the land and into surface waters. The nitrate in solution can also leach into ground water or tile water by the flow of rainwater down into the soil (Stevenson and Cole, 1999). Nitrogen is also eroded from the soil, mostly in organic form (Stevenson and Cole, 1999).

Environmental and Health Concerns

Nitrogen in the form of nitrate ends up in surface and ground waters through runoff and leaching. If the nitrate levels in a body of water become too high, it can have adverse affects in humans and in animals. Nitrate by itself is not harmful, but when it is ingested, bacteria in the stomach can convert the nitrate to nitrite (NO_2). When the nitrite is absorbed into the blood stream, it chemically reacts with oxyhemoglobin in the blood and changes it to methemoglobin. This new form of hemoglobin does not transport oxygen and a person or animal can die from lack of oxygen, kind of like suffocation at the cellular level. This condition is called *methemoglobinemia* or blue baby disease. It affects infants more than adults because infants "have weak stomach acids that allow the nitrate reducing bacteria to grow and produce nitrite. In older children and adults, nitrate is not converted to nitrite in appreciable amounts" (Anderson et al., 1998) and therefore is not considered a health risk to this age group. Animals, like cattle, are also susceptible to methemoglobinemia if they drink from water sources with high levels of nitrate.

Due to the health risk, to infants, associated with high nitrate concentrations, the EPA has set a drinking water standard of 10 ppm (10 mg/L) maximum concentration for nitrate (EPA, 2001; Anderson et al., 1998; MPCA, 1998). There is also a nitrite drinking water standard of 1-ppm (1 mg/L) maximum concentration (EPA, 2001). Thus, it is important to determine how much nitrogen should be applied to a field so that as little as possible end up in water systems (Sutton and Joern, 1992; Stevenson and Cole, 1998).

Phosphorus.

Phosphorus Use and Loss

Phosphorus is used by a plant for a number of different functions including flower budding, seed development, growth and development of roots, disease resistance, cellular functions, and regulating other nutrients in the plant (Evans, 1993; Gaines, 1977). When manure is applied to a field, the phosphorus in it generally occurs as calcium phosphate, or ammonium phosphate, but it is normally expressed as P_2O_5 (phosphoric acid) or as elemental P in research literature (Baker et al., 1997). In order for phosphorus to be absorbed by plants, the phosphorus has to be an orthophosphate ion ($H_2PO_4^-$ and HPO_4^{-2}) or phosphorus in solution (Zhang et al., 1998).

The phosphorus in the manure "...is initially soluble in water" (Zhang et al., 1998), so to make the phosphorus available to the plants, the manure is incorporated (mixed) into the soil and it dissolves in the soil water. As the phosphorus interacts with the soil it may be adsorbed onto the surface of clay particles or it may form precipitates with calcium, iron, or aluminum (Johnson et al, 1998). This causes a portion of the phosphorus to come out of solution, which means that only a small amount of phosphorus is in solution for plants to use.

When a rain event occurs, the water interacts with the thin surface layer of the soil causing dissolved and particulate phosphorus to be washed away in runoff water. The phosphorus, adsorbed to the clay particles, is eroded way along with the particles of soil they are attached to. The dissolved phosphorus may also leach from the soil into tile and groundwater. There is less phosphorus that is loss due to leaching because phosphorus tends to be adsorbed to the soil particles as the water carries the phosphorus down through the soil. Also, less sediment ends up in tile water (Baker and Tidman, 2001; Sutton and Joern, 1992). Only if the soil is sandy without much clay particles and/or if phosphorus has been applied to the soil in excess for an extended period of time will there be high level of phosphorus in ground and tile water.

Environmental and Health Concerns

Phosphorus can end up in surface waters and to a small degree in groundwater through runoff, erosion, and leaching. The phosphorus, which ends up in the surface waters, can be utilized by growing aquatic plants and algae. Phosphorus amounts in the water generally dictate how much growth of aquatic plants and algae can occur because phosphorus is usually a limiting nutrient. If high levels of phosphorus end up in the water, *eutrophication* will occur and algae and plants will grow excessively. Later, when the algae and plants die, bacteria in the water use up a lot of oxygen from the water in order to break down the dead plant material. This can virtually use all the oxygen in the water. The low levels of oxygen in the water will cause aquatic animals to die. This condition is called *hypoxia* (Stevenson and Cole, 1999; Baker and Tidman, 2001; Sutton and Joern, 1992).

Even though large amounts of phosphorus in the water can cause eutrophication leading to hypoxia and possible death of aquatic organisms, there is neither a primary drinking water standard nor a secondary drinking water standard for phosphorus (EPA 2001; MPCA, 1999a). This may be because there are no know health problems associated with high potassium concentrations in drinking water. However, for the sake of the environmental impacts phosphorus, MPCA (1999a) suggests that anything above a maximum phosphorus concentration limit of 100 μg/L (10 ppb) may be cause for concern. It is, thus, important to determine how much phosphorus is applied to fields to keep as much of it, from entering water systems, as possible.

Potassium.

Potassium Use and Loss

Potassium (K) is used by a plant for a number of different functions including root formation, growth of flowers and fruit, disease resistance, exerting a balancing effect on cellular reactions, and transport of carbohydrates throughout the plant (Evans, 1993; Gaines, 1977). According to Rehm (1997), potassium is usually found in three forms: unavailable, slowly available, and readily available (availability is in reference to what plants can utilize). The unavailable potassium is that which is apart of minerals and rocks in the soil. The slowly available potassium is that potassium which has moved out of solution and either is adsorbed to the surface of clay sized particles in the soil or has become precipitates by reacting with other ions. The readily available potassium is the potassium in solution. In order for plants to absorb potassium, it must be in solution as K^+ (potassium ion) (Baker et al., 2001). Even thought potassium in manures and fertilizers are in the forms like KCl, it is normally expressed as either K_2O (potassium oxide) or K in research publications (Baker et al., 2001).

When manure is applied to a field, the potassium from the manure is in a water-soluble form, like potassium chloride (KCl) (Baker et al, 2001). A large percentage of this potassium is adsorbed to soil particles or becomes precipitates, while a small percentage stays in solution. During a rain event, in the thin upper layer of the soil, potassium will either be eroded away with the sediment it has attached to or it will be washed away as a precipitate. The small amount in solution can also be washed away in the runoff or can be leached down through the soil and end up in ground or tile water. Most of the potassium in solution, however, will be adsorbed to the soil before it can actually end up in the ground or tile water. Only if the soil is sandy and low in clay and/or if potassium has been overly applied to the soil, will the potassium be less likely to adsorb to the soil, and leach into tile and ground water (Baker et al., 1983; FMA 2001).

Environmental and Health Problems

Potassium, like nitrogen and phosphorus, can also end up in surface and ground water through runoff, erosion, and leaching. However, unlike nitrogen, which has an EPA drinking water standard for both nitrate and nitrite (EPA, 2001), potassium has neither a primary drinking water standard nor a secondary drinking water standard (EPA, 2001; MPCA, 1999b). In fact, "groundwater with high concentrations of … potassium is considered 'soft' and therefore generally desirable for drinking" (MPCA, 1999b). This may be because, "there are no environmental or health concerns about potassium" (FMA 2001). In any case, it would still do well to have the potassium on the fields where it can nourish growing plants instead of in water bodies were the plants cannot acquire them.

Pathogens in Manure

In addition to adding valuable nutrients to the soil, the application of manure also adds fecal organisms as well. Some of these fecal organisms may be pathogenic and their potential movement from the soil, in which they are applied, into bodies of water could cause health problems to those who utilize these bodies of water for their water consumption needs or for recreational uses.

Pathogens and Indicator Organisms (Criteria for Indicator Organisms)

Fecal organisms consist of a whole host of different organisms ranging from bacteria and protozoa to viruses, fungi, and worms. These organisms live in the gastrointestinal tract of host-organisms. Depending on the type of fecal organism, they may be essential components to a healthy working gastrointestinal tract, or they could be pathogenic and cause health problems for the host organism. Testing for these pathogenic microorganisms in the environment can be expensive, time consuming, and dangerous. Thus, tests for detecting the presence of pathogenic organisms involve testing for indicator organisms instead. Indicator organisms are also fecal organisms, which occur naturally in the gastrointestinal tract of animals. The fecal organisms used must meet the criteria listed in Table 1.4 in order to be considered for use as an indicator organism.

Some of the more commonly used indicator organisms are total coliforms, fecal coliforms, total streptococci, fecal streptococci, enterococci, *Escherichia coli*, anaerobic bacteria, and bacteriophages. For the most part, this literature review just focuses on the total coliforms, fecal coliforms, fecal streptococci, and enterococci bacteria, which are the more widely used indicators of pathogenic and fecal contamination.

Total coliforms are "aerobic & facultative anaerobic, gram-negative non-spore-forming, rod-shaped bacteria" (Britton, 1999). A few examples of these bacteria are *Escherichia coli* (*E. coli*), *Enterobacter, Klebsiella*, and *Citrobacter*. These bacteria are good for detecting the presence of other fecal bacteria but are not as hardy as the viruses and protozoan cysts. A subgroup of total coliforms, fecal coliforms are thermotolerant and can ferment lactose at 44.5° C (Britton, 1999). A few examples of fecal coliform bacteria are *Escherichia coli* (E. coli) and *Klebsiella pneumonae* (Britton, 1999). Just like the bigger group of total coliforms, fecal coliforms are good for indicating the presence of most pathogenic bacteria, but are not good at indicating the presence of viruses and protozoan cysts (Britton, 1999).

Table 1.4 Criteria for indicator organism qualification.

	Criteria for Indicator Organism Qualification	References
1	Must be a naturally occurring microorganism found in the digestive tract of warm-blooded animals	(Britton, 1999) (Byappanahalli et al., 1998)
2	"Should be present when pathogens are present and absent in uncontaminated samples"	(Britton, 1999) (Dutka, 1973);
3	Should be found in greater numbers than the pathogens	(Britton, 1999) (Dutka, 1973)
4	Should be at least, but not less, resistant to the environment as the pathogens of concern	(Britton, 1999) (Dutka, 1973)
5	Should "not be able to proliferate [multiply] to any greater extent than the pathogens in the … environment"	(Dutka, 1973) (Britton, 1999) (Byappanahalli et al., 1998)
6	"Should be detectable by means of easy, rapid, and inexpensive methods"	(Britton, 1999) (Dutka, 1973)
7	Should be nonpathogenic	(Britton, 1999)

Fecal streptococci are gram-positive, cocci (circular shaped) bacteria that "give a positive reaction with Lancefield's Group D antisera (Hagedorn, No Date; Todar, 2002). A few examples of them are *Streptococcus faecalis, S. bovis, S. equines,* and *S. avium* (Britton, 1999; Hagedorn, No Date). A subgroup of the fecal streptococci is enterococci. Enterococci are good for indicating the presence of viruses (Britton, 1999).

Indicator Bacteria and the Criteria of Persistence

One of the criteria of an indicator organism (as stated in Table 1.3) is that it should not multiply in the environment any more than the pathogen being indicated does (Britton, 1999; Dutka, 1973; Byappanahalli et al., 1998). Thus, indicator organisms like E. coli, fecal streptococci, and fecal coliform, which are present in manure, should only persist as long as the pathogens do once being applied to the soil. However, a look at some of the literature presents conflicting observations on whether these bacteria do persist and/or multiply in the environment or not. Stoddard et al. (1998) commented that "fecal coliform concentration, as an indicator of potentially serious bacterial pathogens, usually decline below detectable levels within 60 days of manure application, which corresponded to the time needed for the fecal coliforms to die-off at the soil surface." Gelreich et al. (1962) observed that "...fecal coli-aerogenes bacteria are usually absent or present only in comparatively small numbers in undisturbed soils. There was, however, a sharp increase in the number of these types from soils known to be polluted." And Lau et al. (2001) observations' indicated "...that quantitative analyses of Wisconsin soils in late spring/early summer for either E. coli or enterococci may be useful in determining the likelihood of recent bovine manure application and, thus, the potential risk of enteric pathogens being present." In contrast to these observations, Byappanahalli et al. (1998) revealed that "... fecal bacteria are able to establish a relatively small, but significant population." Also, "the presence of fecal indicator bacteria in Hawaii's soil environment represents a significant, non-fecal environmental source of these bacteria..." (Byappanahalli et al., 1998). Dutka (1973) also noted "...coliforms are able to grow and multiply readily under natural conditions." Faust, (1982) indicated, "from [their] studies, it could not be determined how long fecal coliform bacteria may have been on the surface of the soil." In addition, Roll et al. (1997) observed "the presence of high concentrations of fecal coliforms, E. coli, and enterococci in soil ..., indicating that soil rather than sewage or animal feces is the major environmental source of fecal indicator bacteria recovered." And Vasseur et al. (1996) stated "Even if results after the first year show a significant decrease in indicator bacteria, ... bacteria numbers can significantly increase in the second year, increasing the potential level of contamination." These conflicting observations bring up the question of whether the coliforms and streptococci bacteria should be used as indicators in soils.

A closer look at the research conducted reveals factors like temperature, moisture, and nutrient availability, among others, which may be the connecting causes behind the different observations. These factors may be heavily influenced by the geographical and environmental conditions at a particular location (Geldreich et al., 1962; Byappanahalli et al, 1998; Vasseur et al, 1998), and all of these factors work together to effect the survival of indicator bacteria.

Temperature. Many authors indicated that temperature was a big influence on how long the indicator bacteria could survive in the soil (Placha et al., 2001; Entry et al., 2000b; Byappanahalli et al., 1998; Vasseur et al., 1996). If the soil was warm (in combination with high moisture), the number of indicator bacteria stayed at application levels or increased

(Entry et al., 2000a; Roll et al., 1997). If the temperature was cooler (especially in combination with high moisture), the indicator bacteria decreased in numbers (Chandler et al., 1978; Stoddard et al., 1998; Vasseur et al., 1996). However, if the temperature is cool and moisture is low, the bacteria can survive for a time. (Faust, 1982; Lau et al., 2001).

Moisture/Soil dry matter. A second factor that effects the survival of indicator bacteria is the moisture content of the soil (Byappanahalli et al., 1998). This also correlates with the dry matter content of the soil or percentage/weight of wet soil left after it has been dried at 105 C to remove all water content (Plancha et al., 2001; Chandler et al., 1978). When the soil is moist, the indicator organisms persisted (Roll et al., 1997; Entry et al., 2000a and 2000b; Chandler et al., 1980; Chandler et al., 1978), but when the soil dry matter content is high the indicator organisms decrease in numbers (Chandler et al., 1980; Chandler et al, 1978).

Nutrient Availability. A third factor that effects the survival of indicator organisms is nutrient availability. When the proper types and amounts of nutrients that the indicator organisms need are available, they tend to persist and multiply in the environment (Byappanahalli et al., 1998; Entry et al., 2000b; Stoddard et al., 1998).
It is possible however for there to be lots of nutrients in the soil, yet because of how tightly bound the nutrients may be to the soil, the indicator organisms may not be able to obtain them (Chandler et al., 1980).

Land slope. The slope of the land being tested may also be a significant factor leading to differences in indicator organism persistence and multiplication. In the research conducted by Vasseur et al. (1996) it was found that the number of indicator bacteria on low-sloping land was greater than that found on high-sloping land. This may be due to having more bacteria movement on high-sloping areas from runoff and erosion than on low-sloping areas. Thus the bacteria population in soils with low slopes can grow into a large population more quickly because few bacteria are washed out of the soil so that the present bacteria start off with a larger number to grow from as opposed to the high-sloped area bacteria which will have to start with fewer bacteria to increase numbers from.

pH/ Soil Type/ Others. Vasseur et al. (1996) also noted "the acidity of the Quebec soils may also affect the survival of pathogens in the soil." This and other components like soil type (Gelreich et al., 1962) may also play a major factor in how indicator bacteria survival and for how long.

Since the environmental factors for any given location can vary to the extent of effecting persistence rates of indicator bacteria, what can be done to make testing for indicator organisms more efficient with respect to detecting possible pathogenic fecal organisms (Byappanahalli et al., 1998)? One commonly stated suggestion has been to test the soil in an area for the background levels of different indicator organisms. Such a test area should not be "…influenced by human or agricultural operations…" (Entry et al., 2000a). Thus, the area can be used as a comparison for areas that are used for agriculture and other operations. If the background concentration levels of indicator organisms are naturally high, like in the case with Byappanahalli et al. (1998), then other indicator organisms besides those that are present in high levels may need to be considered. Roll et al. (1997) suggested that " *C. perfringens* was a superior indicator … when compared with the fecal indictors (fecal coliform, E. coli, and enterococci)" for testing soils in Hawaii.

If, however, the indicator organism background levels are low, then any of the indicator organisms could be used for testing soils. The background concentrations would just need to be taken into consideration. Since large groups such a total coliform and fecal coliform or fecal streptococci have members from varying origins and with differing survival rates (Faust, 1982), Doran et al. (1979) suggested testing for specific indicator organisms instead of general groups. This would help narrow the range of background indicator organisms, which could interfere with test results.

Currently, the EPA is in the process of updating its publication on Implementation Guidance for Ambient Water Quality Criteria for Bacteria. In the draft version, made available to the public in 2002, the EPA addresses the concerns related to possibly using alternative indicator organisms in the tropical regions of the US. An EPA-funded workshop was conducted in Hawaii in May 2001, in which "international experts who either have conducted studies or who were otherwise very familiar with the scientific data base regarding *E. coli* or enterococci indicator persistence and growth in tropical environments were tasked to determine if these indicators remained appropriate for determining water quality and associated exposure risks for gastrointestinal disease in recreational waters (EPA, 2002)." The final report from this workshop has not yet been completed, however, in the draft version of Implementation Guidance for Ambient Water Quality Criteria for Bacteria, the EPA has decided that current data are not sufficient to warrant change of presently used indicator organisms to something different for tropical areas. Never the less, should the Hawaii workshop report yield information to the contrary, the information will be considered and research into alternative indicator organisms for tropical environments will be conducted (EPA, 2002).

Thus at present, the EPA still holds to the use of *E.coli*, fecal streptococci, and fecal coliform as the main indicator organisms for testing of drinking and recreational waters for the United States.

BMP's

Knowing that the nutrients nitrogen, phosphorus, and potassium are found in manures in different ratios from that needed by crops, that nutrients are loss from the soil by runoff and leaching, that different nutrients react to loss mechanisms differently, and that these nutrients when loss from the soil end up in water systems and potentially cause health and environmental problems to those who utilize these water systems; the question that comes up is what methods can be taken to apply the right amounts of each nutrient to the soil such that there is not too much of any one nutrient, which could be loss from the soil through runoff and leaching mechanisms?

Past research into this question has yielded what have come to be known as best management practices (BMP). BMP's are methods of agricultural practice that help to address some sort of environmental/health impacts that past practices may have neglected while still maintaining high agricultural production. BMP's have been created for all areas of agriculture addressing nutrients, pesticides, and pathogens loss, erosion issues, irrigation issues, gas emissions from confinement operations, composting, tillage practices, and waste management (Fishel et al., 1992; Canter, 1997). While BMP's appear to be individual methods that can be applied to any given situation, they are actually part of a collection of methods geared towards dealing with specific issues for a specific place (OTA, 1990). Each place and situation requires the planning and implementation of its own set of BMP's to deal with whatever conditions are in need of being addressed because BMP's may cause different effects based on the soil characteristics, practices used, and other conditions of a given area (OTA, 1990). Thus, the National Resource Conservation Service in each state has set up its own set of technical guidelines for each county within its borders. These technical papers called Field Office Technical Guides (FOTG), which are "... used in each field office, are localized so that they apply specifically to the geographic area for which they are prepared" (NRCS, 2003). This leads us to the question on which this thesis is based. That is, how does a set of BMP's tailored for a given place work to improve water quality when dealing with a specific manure type, namely poultry manure as applied to the soil types of central Iowa. Chinkuyu et al. (2000) set out to answer that question when he initiated a six-year study to determine the effects of poultry manure on tile water quality and runoff water quality on central Iowa soils. Chinkuyu obtained the first three years of data for the six-year study and was able to conclude the following things:

1. **Yields and Grain Quality**

   Yields – "The use of laying hen manure in field plots resulted in significantly higher corn and soybean yields when compared with commercial N fertilizer treatment. In addition, application of manure to lysimeters at a rate of 336 kg N/ha resulted in significantly higher corn yields in comparison with the N application rates of 168 kg N/ha from UAN fertilizer or 168 kg-N/ha from laying hen manure" (Chinkuyu et al., 2002).

Grain Quality – "Application of manure did not result in any significant effect on the quality of corn and soybean grains in terms of protein, oil, and starch contents" (Chinkuyu et al., 2002).

2. NO_3-N Subsurface and Runoff Loss

NO_3-N Loss by Subsurface Drainage - "The N application rate of 336 kg-N/ha from laying hen manure resulted in the highest NO_3-N … concentrations in subsurface drain water in comparison with the N application rates of 168 kg-N/ha from UAN fertilizer and 168 kg-N/ha from laying hen manure. The N application rate of 168 kg-N/ha from manure resulted in significantly lower NO_3-N loss with subsurface drain water in comparison with NO_3-N loss from the other two N treatments" (Chinkuyu et al., 2002; Chinkuyu, 2000).

NO_3-N Loss by Runoff – "The manure application rate had no significant effect on NO_3-N concentration in surface runoff water" (Chinkuyu et al., 2002; Chinkuyu, 2000).

3. PO_4-P Subsurface and Runoff

PO_4-P Loss by Subsurface Drainage – "The N application rate of 336 kg-N/ha from laying hen manure resulted in the highest … PO_4-P concentrations in subsurface drain water in comparison with the N application rates of 168 kg-N/ha from UAN fertilizer and 168 kg-N/ha from laying hen manure" (Chinkuyu et al., 2002; Chinkuyu, 2000).

PO_4-P loss by runoff - "The N application rate of 336 kg-N/ha from laying hen manure resulted in a higher concentration of PO_4-P in surface runoff in comparison to the lower N application rate of 168 kg-N/ha from laying hen manure. Higher concentrations of PO_4-P were observed in surface runoff when compared with PO_4-P concentrations in subsurface drain water" (Chinkuyu et al., 2002; Chinkuyu, 2000).

4. **Bacteria Subsurface and Runoff Loss**

   Bacteria Loss in Subsurface Drainage and Runoff – "The N application rate of 336 kg-N/ha from poultry manure (twice the recommended N application rate) resulted in higher concentrations of fecal streptococcus, Escherichia coli, and fecal coliform bacteria in surface and subsurface drain water in comparison with the N application rate of 168 kg-N/ha from poultry manure or commercial fertilizer" (Chinkuyu, 2000). "Application of poultry manure to lysimeters resulted in higher concentrations of bacteria in subsurface drainage water in comparison with the ... field plots" (Chinkuyu, 2000). "Surface runoff water from plots treated with poultry manure had higher concentrations of fecal streptococcus and E.coli in comparison with the concentrations in subsurface drain water from plots under the same treatments." (Chinkuyu, 2000)

It is the goal of the project is to finish collecting the last three years of data for the six-year study started by Chinkuyu, after which, the total six-years of data will be analyzed and conclusions will be drawn based on the same parameters initially addressed by Chinkuyu. Currently, data for the sixth and final year are still being collected. This thesis will present all of the data collected up through the summer of the sixth year.

Objectives

The objective of this research is to understand how poultry manure, applied to fields, impacts tile drainage and runoff water quality. Specific objectives were:

1. To determine how different rates of poultry manure effect crop yields, grain quality, and plant stalk nitrogen uptake in comparison to using a commercial fertilizer.
2. To determine how different rates of poultry manure effect NO_3-N and PO_4-P nutrient concentrations in the soil over time in comparison to using a commercial fertilizer.
3. To determine how different rates of poultry manure effect NO_3-N and PO_4-P nutrient concentrations and losses in subsurface tile water and runoff water in comparison to using a commercial fertilizer.
4. To determine how different rates of poultry manure effect bacteria concentrations in subsurface tile and runoff water in comparison to using commercial fertilizer.

References

Anderson, James; Liukkonen, Barbara; and Bergsrud, Fred. 1993. *Safe Drinking Water for Minnesotans: Indicators of Health Risk.* University of Minnesota Extension Service. Publication FO-00814. http://www.extension.umn.edu/distribution/naturalresources/components/0814-04.html (Date accessed: November 17, 2003)

Baker, R.D.; Ball, Shane T.; and Flynn, Robert. 1997 *Soil Analysis: A Key to Soil Nutrient Management.*" College of Agriculture and Home Economics, New Mexico State University. Electronic version: Sept. 1997. Guide A-137. http://www.cahe.nmsu.edu/pubs/_a/a-137.html (Date accessed: November 17, 2003)

Baker, J.L. and Laflen, J.M. 1983. Runoff losses of nutrients and soil from ground fall-fertilized after soybean harvest. *Trans. of ASAE* 26(4): 1122-1127.

Baker, James and Tidman, Michael J. 2001. Phosphorus losses to Surface Water. Integrated Crop Management. Department of Entomology, Iowa State University, Ames, Iowa. May 14, 2001. Publication IC-486(9). (Date accessed: November 17, 2003) http://www.ent.iastate.edu/ipm/icm/2001/5-14-2001/ploss.html

Beyer, Scott R. 2002. *Frequently Asked Questions About Poultry.* Kansas State University Research and Extension. Publication not numbered. http://www.oznet.ksu.edu/poultry/faq.htm#E.%20Layers (Date accessed: November 17, 2003)

Bitton, Gabriel. 1999. *Wastewater Microbiology.* 2nd ed. Gainsville. New York: John Wiley and Sons, Inc.

Byappanahalli, M.N., and R.S. Fujioka. 1998. Evidence that tropical soil environment can support the growth of *Escherichia coli. Water Science Technology* 38(12): 171-174.

Canter, Larry W. 1997. *Nitrates in Groundwater.* Boca Raton, Florida: Lewis Publishers.

Chandler, D.S. and J.A. Craven. 1978. Environmental factors affecting *Escherichia coli* and *Salmonella typhimurium* numbers on land used for effluent disposal. *Australian Journal of Agricultural Research* 29:577-585.

Chandler, D.S. and J.A. Craven. 1980. Relationship of soil moisture to survival of *Escherichia coli* and *Salmonella typhimurium* in soils. *Australian Journal of Agricultural Research* 31:547-555.

Chinkuyu, Adion. 2000. Environmental impacts of the use of poultry manure for agricultural production systems. PhD dissertation. Ames, Iowa: Iowa State University, Department of Agricultural and Biosystems Engineering.

Chinkuyu, Adion, R.S. Kanwar, J.C. Lorimor, H. Xin, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. *Transactions of the ASAE* 45(2): 299-308.

Doran, J.W., and D.M. Linn. 1979. Bacteriological quality of runoff water from pastureland. *Applied and Environmental Microbiology* 37(5): 985-991.

Dutka, B.J. 1973. Coliforms are an inadequate index of water quality. *Journal of Environmental Health* 36(1):39-46.

Edwards, D.R., and T.C. Daniel. 1992. Environmental impacts of on-farm poultry waste disposal: A review. *Bioresources Technology* 41(1): 9-33.

Entry, James A., Robert K. Hubbard, Janice E. Thies, and Jeffrey J. Fuhrmann. 2000a. The influence of vegetation in riparian filter strips on coliform bacteria: I. Movement and survival in water. *Journal of Environmental Quality* 29:1206-1214.

Entry, James A., Robert K. Hubbard, Janice E. Thies, and Jeffrey J. Fuhrmann. 2000b. The influence of vegetation in riparian filter strips on coliform bacteria: II. Survival in soils. *Journal of Environmental Quality* 29:1215-1224.

Evans, John. 1993. *The Complete Book of Houseplants: A Practical Guide to Selecting and Caring for Houseplants*. New York: Viking Studio Books.

Faust, Maria A. 1982. Relationship between land-use practices and fecal bacteria in soils. *Journal of Environmental Quality* 11(1): 141-146.

Fertilizer Manufacturers Association (FMA). 2001. "Potassium (K)." Nov. 14, 2001. Fertilizer Manufacturers Association, UK. http://www.fma.org.uk/potassium.html (Date accessed: November 17, 2003)

Fishel, David K., Mary Jo Brown, Kevin M. Kostelnik, and Mary A. Howse. 1992 *Evaluation of Agricultural Best-Management Practices in the Conestoga River Headwaters, Pennsylvania: Description and Water Quality of the Little Conestoga Creek Headwaters Prior to the Implementation of Nutrient Management*. U.S. Geological Survey. Water-Resources Investigation Report 90-4131. Lemoyne, Pennsylvania.

Fulhage, C.D. 1993. *Reduce environmental problems with proper land application of animal wastes*. Columbia, MO: University of Missouri.

Gaines, Richard L. 1977. *Interior Plantscaping: Building Design for Interior Foliage Plants*. New York: Architectural Record Books

Geldreich, E.E., C.B. Huff, R.H. Bordner, P.W. Kabler, and H.F. Clark. 1962. The faecal coli-aerogenes flora of soils from various geographic areas. *Journal of Applied Bacteriology* 25(1): 87-93.

Giddens, J., and A.P. Barnett. 1980. Soil loss and microbiological quality of runoff from land treated with poultry litter. *Journal of Environmental Quality* 9(3):518-520.

Greppi, M. and F. Preti. 1999. Volume 1, Section 5.8: Water Quality in Agriculture. *CIGR Handbook of Agricultural Engineering: Land and Water Engineering*. . St. Joseph, Missouri: American Society of Agricultural Engineers.

Hagedorn, Charles and Nancy Love. (Updated monthly.) Environmental Microbiology Web Page (BIOL/CEE/CSES 4984) Maintained by Virginia Polytechnic Institute and State University (VA Tech). http://soils1.cses.vt.edu/ch/biol_4684/ (Date accessed: November 17, 2003)

Johnson, G.V.; Basta, N.T.; Zhang, H.; Hattey, J.A.; Raun, W.R.; and Stiengler, J.H. "Science-Based Animal Waste Phosphorus Management for Oklahoma." *Production Technology.* (January 1998) Vol. 10, No.1. Oklahoma CoOperative Extension Service, Department of Plant and Soil Science, Oklahoma State University. http://clay.agr.okstate.edu/animalwaste/waste1.html (Date accessed: November 28, 2001)

Lau, M.M. and S.C. Ingham. 2001. Survival of faecal indicator bacteria in bovine manure incorporated into soil. *Letters in Applied Microbiology* 33:131-136.

Minnesota Pollution Control Agency (MPCA). 1998. *Nitrate in Minnesota Ground Water: A GWMAP Perspective.* Minnesota Pollution Control Agency. Sept. 1998. Publication not numbered. (Date accessed: November 17, 2003) http://www.seagrant.umn.edu/groundwater/pdfs/MPCA-Nitrate.pdf

Minnesota Pollution Control Agency (MPCA). 1999 (1). P*hosphorus in Minnesota's Groundwater.* Environmental Outcomes Division, Minnesota Pollution Control Agency. May 1999(1). Publication not numbered. (Date accessed: November 17, 2003) http://www.seagrant.umn.edu/groundwater/pdfs/MPCA-Phosphorus.pdf

Minnesota Pollution Control Agency (MPCA). 1999 (2). *Sodium and Potassium in Minnesota's Ground Water.* Environmental Outcomes Division, Minnesota Pollution Control Agency. May 1999 (2). Publication not numbered. http://www.seagrant.umn.edu/groundwater/pdfs/MPCA-Sodium.pdf (Date accessed: November 17, 2003)

Office of Technology Assessment (OTA). November 1990. *Beneath the Bottom-Agricultural Approaches to Reduce Agrichemical Contamination of Ground Water.* Publication OTA-F-418. US Congress, Washington D.C. http://www.wws.princeton.edu/~ota/ns20/year_f.html (Date accessed: November 17, 2003)

Plachá, I., J. Venglovský, N. Sasáková, and I.F. Svoboda. 2001. The effects of summer and winter seasons on the survival of *Salmonella typhimuriam* and indicator micro-organisms during the storage of solid fraction of pig slurry. *Journal of Applied Microbiology* 91:1036-1043.

Rehm, George W. 1997. *Understanding Potassium for Crop Production in Nebraska.* NebGuide. (Electronic version: July 1997). Cooperative Extension Resources, University of Nebraska, Lincoln. Publication G82-587-A. http://www.ianr.unl.edu/pubs/soil/g587.htm (Date accessed: November 17, 2003)

Roll, B.M., and R. S. Fujioka. 1997. Sources of faecal indicator bacteria in a brackish, tropical stream and their impact on recreational water quality. *Water Science Technology* 35(11-12): 179-186.

Schwantz, Lee. 1979. "Feeding Instructions." *Farmer's Digest.* Wisconsin. (Referenced from The Family Poultry Flock) Website: CHICKEN FEED:The World of Chickens. http://www.lionsgrip.com/feedinstruc.html Website: CHICKEN FEED:The World of Chickens. (Date accessed: November 17, 2003)

Soil Conservation Service. 1992. *National Engineering Handbook: Agricultural Waste Management Field Handbook.* United States Department of Agriculture.

Stevenson, F.J. and Cole, M.A. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients.* 2^{nd} ed. New York: John Wiley and Sons, Inc,

Stoddard, C.S., M.S. Coyne, and J.H. Grove. 1998. Fecal bacteria survival and infiltration through a shallow agricultural soil: timing and tillage effects. *Journal of Environmental Quality* 27:1516-1523.

Soil Conservation Service (SCS). 1992. *National Engineering Handbook: Agricultural Waste Management Field Handbook.* United States Department of Agriculture. (Table 4-14)

Sutton, Alan L. and Joern, Brad C. 1992. *Land Application of Manure.* (Dec. 1992). Cooperative Extension Service, Purdue University and U.S. Department of Agriculture. Publication WQ-16. http://www.ces.purdue.edu/extmedia/WQ/WQ-16.html (Date accessed: November 17, 2003)

Todar, Kenneth. 2002. *Major Groups of Prokaryotes.* (Date accessed: November 17, 2003) http://www.bact.wisc.edu/Bact303/MajorGroupsOfProkaryotes

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 1999. *Agricultural Statistics 1999.* Publication ID#: No #. www.usda.gov/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2000. *Agricultural Statistics 2000.* Publication ID#: No #. www.usda.gov/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2001. *Agricultural Statistics 2001*. Publication ID#: No #. www.usda.gov/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2002. *Agricultural Statistics 2002*. Publication ID#: No #. www.usda.gov/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2003. *Agricultural Statistics 2003*. Publication ID#: No #. www.usda.gov/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Resources Conservation Service (USDA-NRCS). *electronic Field Office Technical Guides* (eFOTG). http://www.nrcs.usda.gov/technical/efotg/ (Date accessed: November 17, 2003)

U.S. Environmental Protection Agency (EPA). March 2001. *National Primary Drinking Water Standards*. Office of Water, Environmental Protection Agency. Publication EPA 816-F-03-016. http://www.epa.gov/safewater/consumer/mcl.pdf (Date accessed: November 17, 2003)

U.S. Environmental Protection Agency (EPA). May 2002 (Draft). *Implementation Guidance for Ambient Water Quality Criteria for Bacteria*. U.S. Environmental Protection Agency, Office of Water (4305T), 1200 Pennsylvania Ave., NW, Washington D.C. 20460. Publication EPA-823-B-02-003. http://www.epa.gov/ost/standards/bacteria/ (Date accessed: November 17, 2003)

Vasseur, L., C. Cloutier, A. Labelle, J. –N. Duff, C. Beaulieu, and C. Ansseau. 1996. Responses of indicator bacteria to forest soil amended with municipal sewage sludge from aerated and non-aerated ponds. *Environmental Pollution* 92(1): 67-72.

Zhang, Hailin; Johnson, Gordon; and Raun, Bill. 1998. *How Phosphorus Addition and Removal Affecting Soil Test P Index*. Production Technology. (April 1998). Vol. 10, No. 8. Oklahoma CoOperative Extension Service, Department of Plant and Soil Science, Oklahoma State University. (Date accessed: November 28, 2001) http://clay.agr.okstate.edu/animalwaste/Padditio.html

Zhang, Hailin; Hamilton, Douglas W.; and Britton, James G. (No Date) *Using Poultry Litter as Fertilizer*. Oklahoma CoOperative Extension Services, Division of Agricultural Sciences and Natural Resources, Oklahoma State University. Publication F-2246. http://pearl.agcomm.okstate.edu/plantsoil/soils/f-2246.pdf (Date accessed: November 17, 2003)

CHAPTER 2. EFFECTS OF POULTRY MANURE ON GRAIN YIELDS, GRAIN QUALITY, AND CORN STALK N

A paper to be submitted to the Journal of American Water Resources Association (JAWRA)

Melissa Cheatham, Ramesh Kanwar, James Baker, Dan Nettleton

Abstract

A six-year study (1998-2003) was conducted to determine the effects of poultry manure on crop growth parameters (yields, corn stalk N concentrations, and grain quality). Eleven experimental plots were used for this study. Three experimental treatments were used to give N applications at rates of: *i*) 168 kg N/ha from poultry manure (PM), *ii*) 168 kg N/ha from urea-ammonium nitrate (UAN), and, *iii*) 336 kg N/ha from poultry manure (PM2). Each of these treatments were replicated three and four times using ten of the eleven plots. The eleventh plot was used as a check plot with zero application of nitrogen from UAN or poultry manure. These field plots were planted to a corn-soybean rotation. In addition, six lysimeters (2.29m x 0.91m x 1.52 m) were also used for this study with similar N treatments. The results of this indicate that the poultry manure giving an application of 168 kg N/ha resulted in slightly higher yields in comparison with the UAN treatment even though statistically yields were not significantly different. The double rate poultry manure treatment (PM2) also resulted in higher yields in comparison with the PM and UAN treatments but statistically were similar. The overall results of this study indicate that the PM treatment is the better choice in applying nutrients to fields because of higher yields and lower rate of N application to the croplands, which eventually would have better impacts on soil and water quality.

Key Terms: poultry manure, field plots, lysimeters, corn soybean rotation, continuous corn, soybeans

Introduction

Iowa's egg industry continues to grow each year. In 2001 Iowa became the number one egg producing state in the US, producing 8.69 billion eggs (USDA-NASS, 2002). In 2002, Iowa broke its record producing 9.91 billion eggs, thus maintaining its position as number one egg producing state for 2002 (USDA-NASS, 2003) (Table 2.1). In order for Iowa to continue producing such a high number of eggs, an average of 675 million pounds of feed per year would be required leading to the generation of some 817 million pounds of manure every year (Beyer, 2002; Schwantz, 1979; SCS, 1992; USDA-NASS, 2003) (This does not include waste from other types of poultry operations such as broilers etc.) (Table 2.2). With so much poultry manure being generated every year brings the need to find ways to manage this manure so that it does not create environmental problems. The most common way of utilizing manure is to apply it on fields to help add valuable plant nutrients for growing crops. Unfortunately, the amount of nutrients present in the manure typically is not present in the same ratios as are needed by the crops to be grown. This can result in the over application of some nutrients especially phosphorus leading to water quality problems. To help solve water quality problems, policies were developed in Iowa on how much manure could to be applied to fields based on the nitrogen requirements of the crops. Over time the excess phosphorus builds up in the soil and is washed off from fields into runoff and subsurface tile flow. This can lead to other water quality problems. Thus, other methods of nutrient management are needed in order to reduce the high phosphorus levels that have become prevalent in soils that were being overly applied with manure and to prevent phosphorus losses from fields to Iowa's water bodies.

Table 2.1. Iowa's egg industry statistics for the years 1998-2002.

Year	Rank	No. of eggs produced	Average No. of Layers	Rate of Egg Laying Per Year Per Hen
1998	4th	5,969,000,000	23,044,000	259
1999	2nd	6,754,000,000	25,623,000	264
2000	2nd	7,554,000,000	28,098,000	269
2001	1st	8,691,000,000	32,591,000	267
2002	1st	9,910,000,000	36,980,000	268

*Information from the USDA National Agricultural Statistics Service (USDA-NASS, 2003, 2002, 2001, 2000, 1999)

Table 2.2. Calculations for feed use and waste production by laying hens.

Assumptions:

1 Iowa has an average of 36,980,000 layer hens in 2002 (NASS, 2002)
Each layer hen produce 268 eggs per year
Iowa produced 9,910,000,000 eggs in 2002

2 Layer hen cycle = 12 months (Beyer, 2002)

3 0.5 lb of 15% protein feed given per 10 hens per day (Schwantz, 1979)

4 60.5 lb manure/1000 layer hens is produced each day having a volume of 0.93 ft^3 manure/1000 hens/day (value is manure as excreted with moisture being 75% of total wt) (SCS, 1992)

Amount of feed needed to supply Iowa layer hens in a year 2002.

$$36{,}980{,}000 \text{ hens} * \frac{0.5 \text{ lb feed}}{10 \text{ hens} * \text{day}} * \frac{365 \text{ days}}{1 \text{ year}} = \mathbf{\frac{674{,}885{,}000 \text{ lb feed}}{\text{year}}}$$

Amount of manure generated by Iowa layer hens in 2002.

$$36{,}980{,}000 \text{ hens} * \frac{60.5 \text{ lb manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{816{,}610{,}850 \text{ lb manure}}{\text{year}} = \mathbf{\frac{816{,}611{,}000 \text{ lb manure}}{\text{year}}}$$

$$36{,}980{,}000 \text{ hens} * \frac{0.93 \text{ ft}^3 \text{ manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{12{,}552.861 \text{ ft}^3 \text{ manure}}{\text{year}} = \mathbf{\frac{12{,}553{,}000 \text{ ft}^3 \text{ manure}}{\text{year}}}$$

A six-year study was conducted (from 1998 through 2003) in order to better understand how poultry manure applied to field plots impacts crop growth, soil nutrients, and water quality. Specifically, the question being addressed in this study was: what is the optimum application of poultry manure to obtain high corn and soybean yields without the degradation of soil and water quality. Therefore, three experimental treatments were used in this study, to apply poultry manure at rates to give 168 kg N/ha and 336 kg N/ha, and to apply UAN fertilizer at a rate of 168 kg N/ha.

Materials and Methods

Site Location and Experimental Units

This study was conducted in Field 5 at the Iowa State University Agronomy and Agricultural Engineering Research Center located on US highway 30 between Ames and Boone, Iowa (Figure 2.1). The soils in Field 5 are a part of the Clarion-Nicollet-Webster soil association (Blanchet, 1996; Chinkuyu et al., 2002; Chinkuyu, 2000). These soils were derived from glacial till laid down during the last glacial retreat that extended throughout an area of Iowa known as the Des Moines lobe advance (SSD, no date; Chinkuyu et al., 2002; Chinkuyu, 2000) [Figure 2.2]. Originally, these soils yielded prairie vegetation before being converted to productive farmland (Chinkuyu et al., 2002; Chinkuyu, 2000) [More information about Field 5 soils can be obtained in Appendix A.].

Within field 5 are the eleven field plots that were used in this experiment. The field plots, as shown in Figure 2.3, vary in size from 0.19 ha (0.47 ac) to 0.42 ha (1.04 ac). These field plots were established in 1984 and each is drained by a single subsurface tile drain

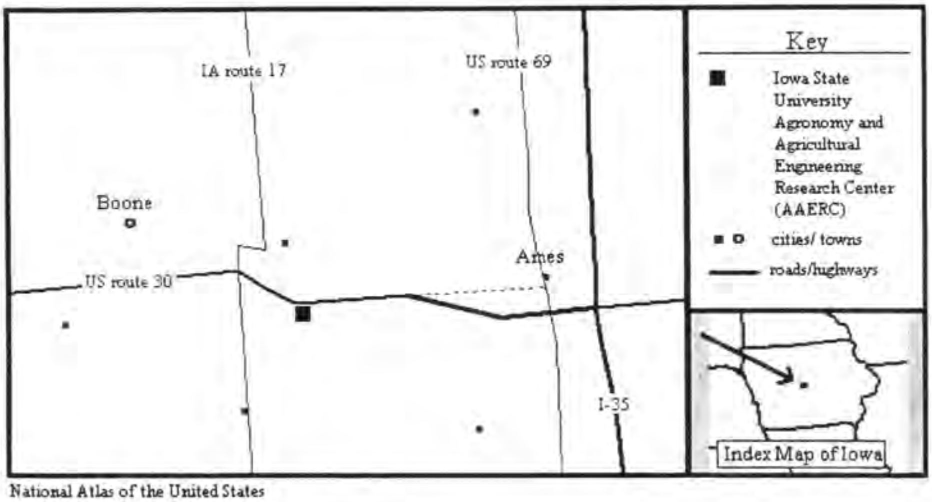


Figure 2.1 Location of Agronomy and Ag. Engineering Research Farm in relation to Ames, and Boone.

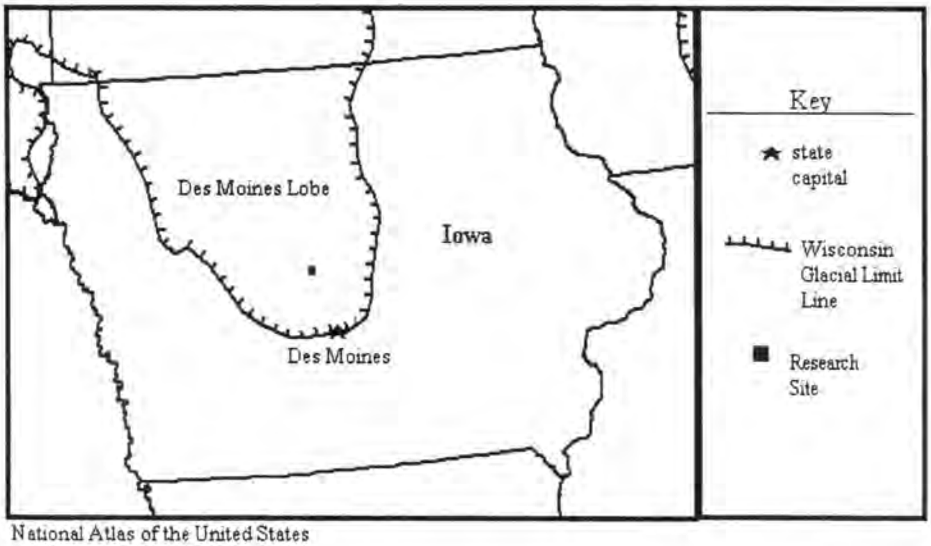
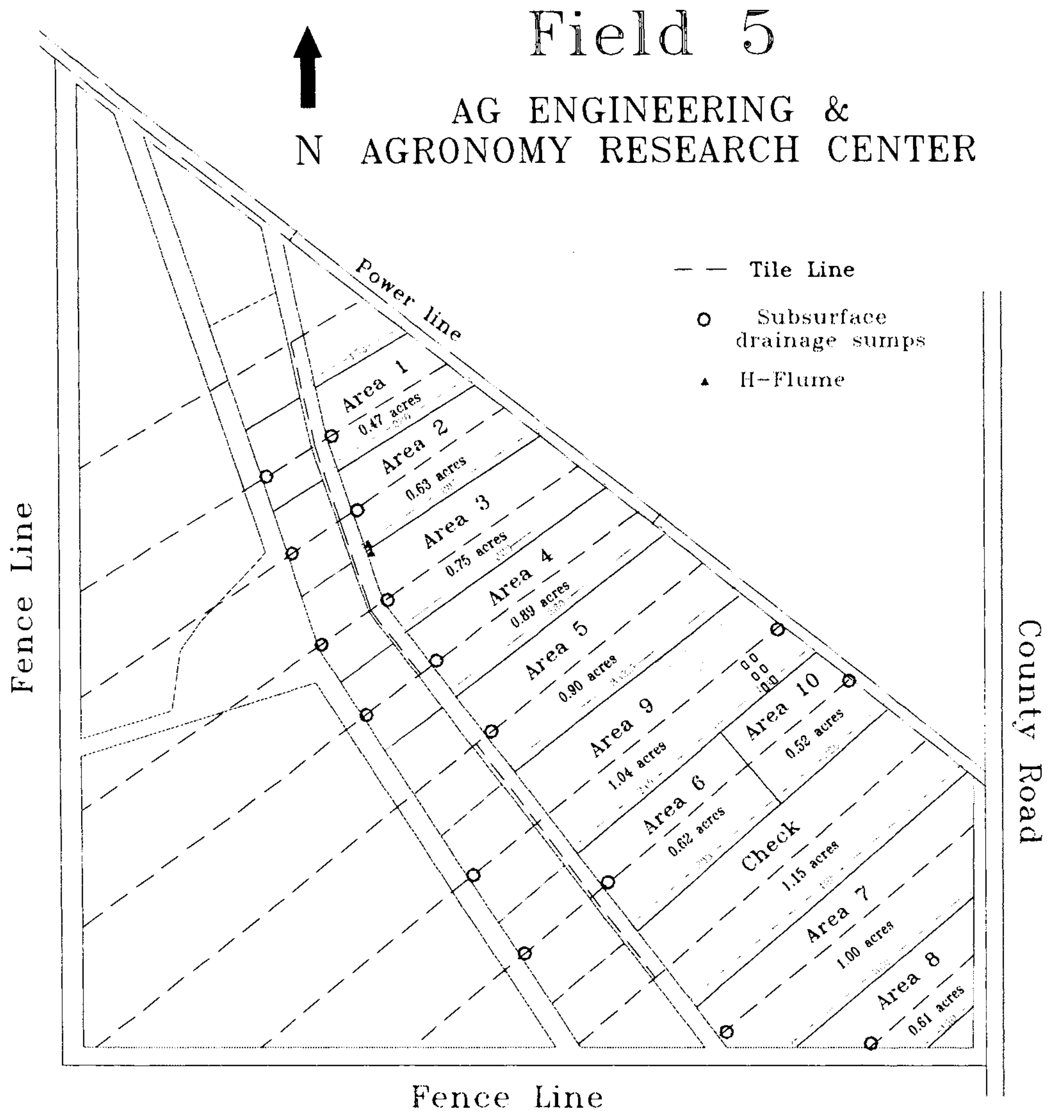


Figure 2.2. Extent Des Moines Lobe Glacial Advance.



1	336 kg-N/ha Poultry Manure	6	168 kg-N/ha UAN Fertilizer
2	168kg-N/ha Poultry Manure	7	336 kg-N/ha Poultry Manure
3	336 kg-N/ha Poultry Manure	8	168 kg-N/ha UAN Fertilizer
4	168 kg-N/ha UAN Fertilizer	9	168 kg-N/ha UAN Fertilizer
5	168 kg-N/ha Poultry Manure	10	168 kg-N/ha Poultry Manure

Check Plot : No Poultry Manure or UAN Fertilizer

Figure 2.3. Field Plots in Field 5.

that runs through the center of the plot and is intercepted by a sump containing monitoring devices for measuring water flow and collecting samples for water quality analysis (Kanwar et al., 1988; Blanchet, 1996). The sump for the control (check) plot was not installed until fall 1999.

Six lysimeters were also used for this study and are located within field plot 9 (Figure 2.4). Constructed in 1992, the lysimeters are arranged in two rows of three with each lysimeter being 381 cm (12.5 ft) apart from each other (Figure 2.5). First, the containers to hold the soil profiles were assembled. Each container consists of three layers: an outer polyethylene plastic layer, a middle Styrofoam layer, and an inner plastic liner (Figure 2.6). Then, using a grave-digging machine, the soil profiles that would be used to fill the lysimeter containers, were removed in 15 and 30 cm deep layers, in such a way, that the profile could be reassembled when the soil would be put in the containers. Once the soil was removed, four soil core samples were taken from the walls in each of the four sides of the holes and tested for hydraulic conductivity, bulk density, and other soil properties, which are given in Blanchet (1996). Then a Bentonite (clay) layer was added to the bottom of the holes before the containers were lowered into them. Afterwards, more Bentonite was used to fill in the space between the lysimeter containers and the walls of the hole. Then, the sump and tile system was installed inside to the lysimeters before finally packing the soil layers into the lysimeters (Figure 2.6). Care was taken to reassemble the original soil profiles. More details on the construction and installation of the lysimeters are given in Blanchet (1996).

Experimental Treatments: Manure/Fertilizer Applications

Laying hen poultry manure used in this experiment was obtained from a laying hen farm located in Humboldt, Iowa. Prior to applying the poultry manure to the field plots and

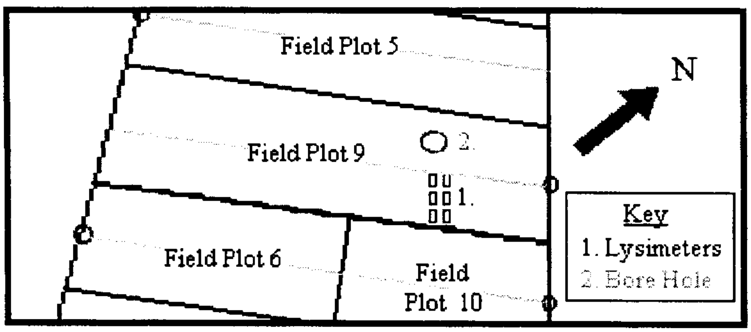


Figure 2.4. Location of Lysimeters.

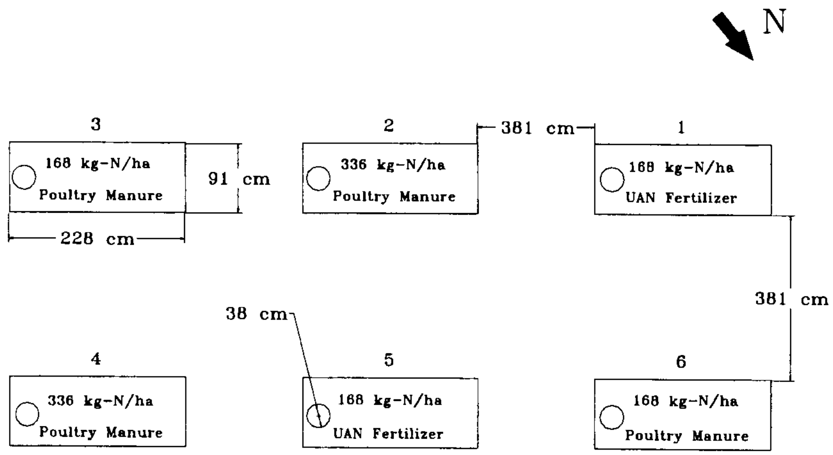


Figure 2.5. Layout of lysimeters to study the effects of N management systems on subsurface drainage water quality.

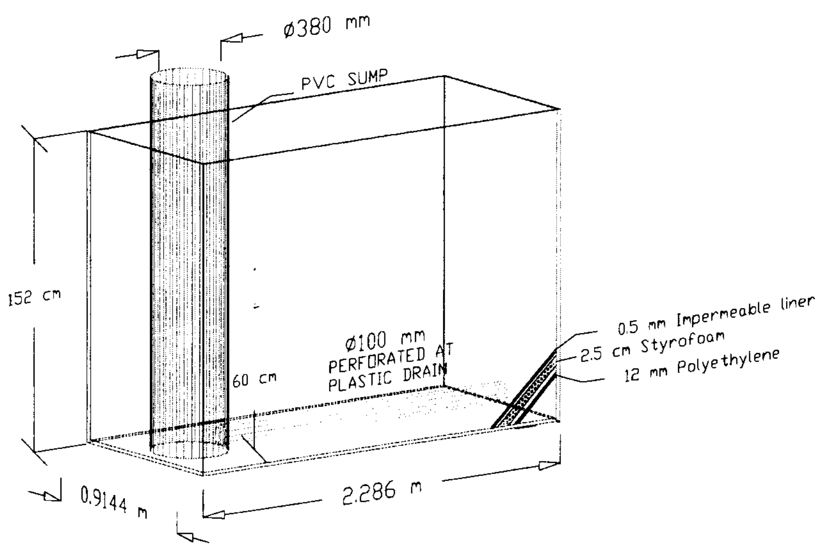


Figure 2.6. Design details of lysimeter construction box to study the effects of N management systems on subsurface drainage water quality.

lysimeters, samples of the manure were taken and sent to MVTL Laboratories, Inc., located in Nevada, Iowa, to test for total moisture, total nitrogen, phosphorus, potassium, and ammonia-nitrogen. Results from the analysis are given in Table 2.3.

Field Plot. The following treatments were applied on the field plots: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), *iii*) 336 kg N/ha from poultry manure (PM2), and *iv*) 0 kg N/ha (control treatment). These treatments were randomly assigned to each field plot, but due to the number of field plots available, the treatments were unbalanced with the UAN treatment having four replicates, PM treatment having three replicates, the PM2 treatment having three treatments, and the control treatment having one replicate. Figure 2.3 shows which field plots received what treatment.

The manure was applied to the field plots by surface broadcast on one half of the plots, which are planted in corn. The other half of each field plot that was planted to soybeans received no manure or N fertilizer. After manure or UAN fertilizer was applied to the field plots, it was incorporated into the soil that day or the day after by tilling/disking the soil down to a depth of about 15 cm (6 inches). This was done to help minimize N losses through volatilization (Chinkuyu et al., 2002; Chinkuyu, 2000).

Lysimeters. The following treatments were applied on the lysimeters: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), and *iii*) 336 kg N/ha from poultry manure (PM2). The treatments were randomly assigned to the lysimeters, giving a total of two replicates per treatment as listed in Figure 2.5. A control treatment was not used for the lysimeters due to the number of lysimeters available for this study (Chinkuyu et al., 2002).

Table 2.3. Characteristics of poultry manure applied to field plots and lysimeters.

Characteristics	1998	1999	2000	2001	2002	2003
Field Plots						
	168 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.49	3.04	2.69	2.16	1.41	2.03
Ammonia (NH_3), %N	1.00	4.37	3.94	2.72	2.24	1.60
Total Phosphorus, %P	1.43	2.29	2.41	20.62	1.20	1.81
Potassium, %K	1.11	0.74	0.72	8.50	0.57	1.71
Moisture Content, %H2O	48.12	45.03	32.60	56.97	53.70	76.25
	336 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.51	2.98	3.73	2.16	1.41	2.03
Ammonia (NH_3), %N	0.94	4.21	3.76	2.72	2.24	1.60
Total Phosphorus, %P	1.25	1.86	2.25	20.62	1.20	1.81
Potassium, %K	1.06	0.82	0.78	8.50	0.57	1.71
Moisture Content, %H2O	46.88	54.60	32.23	56.97	53.70	76.25
Lysimeters						
	168 kg N/ha and 336 kg N/ha Poultry Manure Treatments					
Total Kjedhal N (TKN), % N	1.49	2.98	3.80	6.08	1.06	2.03
Ammonia (NH_3), %N	1.00	4.21	3.73	2.10	3.29	1.60
Total Phosphorus, %P	1.43	1.86	2.37	1.28	1.43	1.81
Potassium, %K	1.11	0.82	0.66	1.32	0.45	1.71
Moisture Content, %H2O	48.00	55.00	27.90	56.90	58.20	76.25

*Conversion for nutrients: % *20 = lbs/ton

The manure or UAN fertilizer was applied to the lysimeters by hand. First a shovel was used to break up the soil in each lysimeter bed. Then, using a portable balance, the proper amount of manure/fertilizer was weighted on the bases of nitrogen content of the manure/fertilizer being used in a given year. Manure/fertilizer was spread over the surface of each lysimeter, and using the shovel was incorporated into the soil that same day (Chinkuyu et al., 2002). Even though the intended application rates applied to both field plots and lysimeters were based on the nitrogen treatments UAN, PM, and PM2, "the actual amounts of N applied to the plots and lysimeters were different from the desired N application rates because the N content in the manure (determined at the beginning) used in the calibration of the manure spreader was different from the N content determined at the time of application" (Chinkuyu et al., 2002; Chinkuyu, 2000). The actual N application rates for the two treatments averaged: *i*) PM = 170 kg N/ha and *ii*) PM2 = 321 kg N/ha for the field plots and *i*) PM = 254 kg N/ha and *ii*) PM2 = 508 kg N/ha for the lysimeters as shown in Table 2.4.

Planting

The field plots were planted to a corn-soybean rotation in such a way that both corn and soybeans are planted on the same field plot in the same year. Using the center tile drain in the middle of each field as a dividing line, one half of the field plot was planted to corn and the other half was planted to soybeans. In even years, like 1998, corn was planted on the northern half of the fields and soybeans on the southern half. Then in the following year (an odd year, like 1999), corn was planted on the southern half of the fields and the soybeans on the northern half. The corn variety Dekalb 580 and soybean variety Kruger 2426 were used

Table 2.4. Average manure application rates for field plots and lysimeters for six years.

	168 kg N/ha poultry manure				336 kg N/ha poultry manure			
	Average manure application rate, kg/ha	Average application rate, kg/ha*			Average manure application rate, kg/ha	Average application rate, kg/ha*		
		N	P	K		N	P	K
Field Plots								
1998	10674	159	107	152	24190	364	227	303
1999	9575	291	418	220	14774	440	622	275
2000	3213	86	126	78	8741	326	329	196
2001	8998	195	244	1855	14957	324	406	3083
2002	7982	113	179	96	14295	202	320	172
2003	11318	229	181	205	18231	369	292	330
6-yr average	8627	179	209	434	15865	337	366	727
Lysimeter								
1998	15717	234	157	225	31720	473	317	454
1999	2902	86	122	54	5804	173	244	108
2000	2190	83	82	52	4379	166	163	104
2001	10189	620	214	130	20378	1239	428	261
2002	9182	97	302	131	18382	195	605	263
2003	9179	186	147	166	18359	372	294	333
6-yr average	8226	218	171	126	16504	436	342	254

* Assumed 5% N, P, and K lost during application; 75% N, P, and K available during the first year. In subsequent years no credit was given for residual N, P, and K from the manure or N from soybeans.

¶ Intended N application rates from layer manure were 168 kg-N/ha and 336 kg-N/ha, however, actual N application rates averaged PM = 179 kg-N/ha and PM2 = 337 kg-N/ha for the plots; PM = 218 kg-N/ha and PM2 = 436 kg-N/ha for the lysimeters.

Table 2.5. Corn stalk N scale.

Relative Levels	Corn Stalk N (ppm)	Indication
Low	<250	"... high probability that greater availability of N would have resulted in higher yields"
Marginal	250-700	"... N availability was very close to the minimal amounts needed"
Optimal	700-2000	"... high probability that N availability was within the range needed to maximize profits for the producer"
Excessive	>2000	"... high probability that N availability was greater than if fertilizer N had been applied at rates that maximize profits for producers"

*Information obtained from Blackmer et al. (2000)

in the experiment with each being planted at a spacing of 0.75 m between rows and 0.2 m between plants within each row (Chinkuyu et al., 2002; Chinkuyu, 2000).

The lysimeters were planted to continuous corn using Dekalb 580 corn variety. Twelve corn seeds were evenly planted in each lysimeter bed in three rows of four (0.75 m between rows and 0.2 m between plants within each row) (Chinkuyu et al., 2002; Chinkuyu, 2000). If the planted corn seeds did not grow or field rodents ate the seeds, corn plants from the adjacent field plot were dug up and transplanted into the lysimeter beds in order to maintain a population of twelve plants in each lysimeter.

Grain Harvesting

Field Plots. Corn and soybean yields were determined at the time of harvest based on moisture content of 15% for corn and 13% for soybeans. Grain samples were taken to a lab for moisture, protein, starch, and oil contents analysis. Once the moisture content for the grain was obtained from the lab, crop yields for plots were calculated to actual yields.

Lysimeters. The corn from the lysimeters was picked by hand. All the grain yields were determined based on 15% moisture content. The grain samples were also sent to a lab for moisture, protein, starch, and oil contents analysis. Once the moisture content for the grain is obtained from the lab it is used to calculate actual yields.

Determination of Corn Stalk NO_3-N

Field Plot. During harvesting of the corn grain, corn stalk samples are taken to test the stalks for NO_3-N content. The corn stalk NO_3-N levels can give an indication of whether the corn was receiving the right amount of nitrogen up through the end of the plants' growth (Blackmer et al., 2000). A scale for determining this, as explained by Blackmer et al. (2000), is given in the Table 2.5. Using the scale given in Table 2.5 can help farmers determine the amount of manure/fertilizer to add for the next growing season (Blackmer et al., 2000). Before the field plots were harvested, random corn plants are chosen from which to take corn stalk samples. A 20-cm (8-inch) length of the corn stalk is cut from each plant, about 15-cm (6-inches) from the ground (Blackmer et al., 2000). Fifteen corn stalks per field plot were collected and placed in labeled paper bags. The samples were then stored in a cooler until they were taken to the lab for analysis.

Lysimeters. Corn stalk samples from the lysimeters were collected after the corn grain had been harvested. Corn stalk samples were taken from all twelve-corn plants in each lysimeter. The twelve corn stalks were placed in labeled paper bags and stored in a cooler until they were sent to the lab for analysis.

Tillage

Once the field plots had been harvested, the side of each field plot that had corn for that year was tilled using a chisel plow which allows about 30% of the crop residue to remain on the surface of the soil. The side of each field plot that was planted in soybeans did not receive the fall tillage.

Results and Discussion

Statistical Design

The data obtained from this study were tested using a split-plot design model and SAS version 8.2. First the data was tested using an F test. If the results indicated that there were significant differences in the treatments, a student t-test was performed to indicate the significance levels between the treatments. All tests were conducted using an alpha of 0.05.

Corn Yields

The five-year averages, for field plot corn yields obtained from each of the treatments, are given in Table 2.6. These results show that five-year average PM2 treatment resulted in significantly higher corn yields in comparison with the UAN treatment and were also higher than the PM treatment.

The five-year average lysimeter corn yields obtained from each of the treatments are given in Table 2.6. These results show that five year average PM2 treatment yields were significantly higher in comparison with the UAN and PM treatments. There were no significant differences in yields between the UAN and PM treatments. Also, corn yields from lysimeters were much lower than those obtained from the field plots. This was due to the fact that corn growing conditions in lysimeters were different in comparison with the field plots.

Soybean Yields

The five-year average soybean yields obtained from field plots under each of the treatments are given in Table 2.6. These yields show that the control treatment had the lowest whereas the PM2 treatment produced the highest soybean yields. The UAN and PM treatments produced similar yields with the PM treatment having slightly higher yields. Statistically, there were no significant differences in soybean yields among the treatments.

Corn Stalk N

The five-year treatment averages for field plot corn stalk nitrogen concentrations are given in Table 2.6. The data on corn stalk N shows that the PM2 treatment stalk N concentrations were statistically higher in comparison with the UAN and PM treatments. The UAN and PM treatments were not significantly different from each other. Comparing these numbers to the corn stalk N scale, the PM2 treatment produced excessive corn stalk N

Table 2.6. Field plot and lysimeter yields and corn stalk N (1998-2002).

Year	Field Plots				Lysimeters		
	Check#	UAN	PM	PM2	UAN	PM	PM2
Corn Yields (kg/ha)							
1998	4037	8316a*	9338a	9032a	3798b	5460b	9790a
1999	5397	9025b	10357a	10513a	7450b	8603b	10003a
2000	6506	8821b	9934ab	9957a	5989a	7003a	9967a
2001	6186	8079b	9115ab	9348a	1205b	2508b	4377a
2002	4567	9682b	10555ab	11377a	8043b	7160b	10775a
5-yr average	5339	8785b	9860ab	10045a	5297b	6146b	8982a
Soybean Yields (kg/ha)							
1998	3526	4036a	3920a	4254a	---♣	---	---
1999	3486	3609a	3884a	3922a	---	---	---
2000	2306	2746a	3316a	3332a	---	---	---
2001	2497	2763a	3131a	3304a	---	---	---
2002	868	1650b	2415ab	2143a	---	---	---
5-yr average	2537	2961a	3333a	3391a	---	---	---
Corn Stalk N (ppm)							
1998	38	186b	763b	3299a	19a	9a	100a
1999	16	1332a	1286a	1969a	4a	6a	1a
2000	43	2430b	3723b	12725a	498b	20a	56a
2001	20	1290b	1123b	3590a	78a	105a	227a
2002	18	1791a	57a	1242a	577a	0b	385a
5-yr average	27	1406b	1391b	4565a	235a	28a	154a

Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

* Values in the same row followed by the same letter are not significantly different at significance level of P = 0.05. ♣ --- means no data.

levels, the UAN and PM treatments produced optimal corn stalk N levels, and the control treatments produced low corn stalk N levels.

The five-year treatment averages for lysimeter corn stalk nitrogen are given in Table 2.6. This data in Table 2.6 show that the corn stalk N from the UAN treatment is higher in comparison with those from the PM and PM2 treatments but statistically these differences are not significant.

Corn Grain Quality

The harvested corn from the field plots and lysimeters were tested for the grain quality parameters of percent moisture, protein, oil, and starch.

Field Plots

Percent Corn Moisture. The five-year treatment averages for corn percent moisture are given in Table 2.7. These results show that the UAN treatment effects are significantly different from that of the control and PM2 treatments, with the UAN giving the lowest grain moisture content of 13.13%. The PM2 and PM treatment effects were not significantly different from each other, and the PM2 resulted in the highest grain moisture content of 13.68%.

Percent Corn Protein. The five-year averages for corn percent protein show that the PM2 treatment resulted in significantly higher protein content of 7.71% in grain compared to other treatments.

Percent Corn Oil. The five-year averages for corn percent oil content show that the UAN treatment resulted in significantly lower oil content in comparison with other treatments.

Percent Corn Starch. The five-year treatment averages for corn percent starch content show that the PM2 treatments resulted in significantly lower starch content of 60.75% in comparison with the PM treatment.

Lysimeters

Percent Corn Moisture. The data on five-year treatment averages for corn percent moisture show that there were no significant differences between the treatments.

Percent Corn Protein. The five-year treatment averages for corn percent protein show that there were no significant differences between the treatments.

Percent Corn Oil. The five-year treatment averages for corn percent oil are given in Table 2.7. These results show that there were significant differences between treatment effects on corn oil content. The PM treatment effects were significantly different from that of the UAN and PM2 treatment effects, with the PM treatment resulted in the highest oil content of 3.15%. There were no significant differences between the UAN and PM2 treatment effects.

Percent Corn Starch. The five-year treatment averages for corn percent starch show that the PM treatment resulted in significantly higher starch content of 61.25% compared to the UAN and PM2 treatments.

Soybean Grain Quality

The harvested field plot soybeans were tested for the grain quality parameters of percent moisture, protein, oil, and starch.

Field Plots

Percent Soybean Moisture. The five-year treatment averages for soybean percent moisture are given in Table 2.8. These results show that there were significant differences

Table 2.7. Field plot and lysimeter corn grain quality (1998-2002).

Year	Field Plots				Lysimeter		
	Check#	UAN	PM	PM2	UAN	PM	PM2
Moisture (%)							
1998	14.10	9.08	12.37	12.40	6.15	7.00	6.50
1999	10.70	10.18	9.97	10.33	10.45	10.35	9.75
2000	14.20	13.88	13.63	13.77	14.20	14.45	13.60
2001	20.90	22.30	21.83	21.43	16.90	17.75	19.30
2002	10.10	10.20	9.80	10.47	8.95	8.30	9.80
5-yr average	14.00	13.13b*	13.52ab	13.68a	11.33a	11.57a	11.79a
Protein (%)							
1998	5.60	7.00	6.70	7.27	9.10	7.75	8.60
1999	6.30	7.10	7.30	7.60	6.55	5.60	7.00
2000	7.60	8.73	8.43	8.57	8.75	6.95	8.10
2001	6.80	7.10	7.03	7.30	9.65	8.40	9.20
2002	5.70	7.18	6.47	7.83	8.45	6.65	8.60
5-yr average	6.40	7.42b	7.19b	7.71a	8.50a	7.07a	8.30a
Oil (%)							
1998	3.50	3.25	3.50	3.50	2.90	3.15	3.05
1999	3.80	3.68	3.87	3.77	3.70	3.90	3.65
2000	2.90	3.08	3.13	3.07	2.70	2.80	2.60
2001	3.60	3.30	3.43	3.47	3.35	3.65	3.40
2002	3.00	3.15	3.27	3.20	3.40	3.45	3.40
5-yr average	3.36	3.29b	3.44a	3.40a	3.21a	3.39b	3.22a
Starch (%)							
1998	62.00	61.65	61.70	61.40	61.05	61.65	61.25
1999	62.40	61.70	61.33	61.27	62.30	62.95	61.95
2000	61.00	60.03	60.57	60.27	60.35	61.45	61.00
2001	60.30	59.70	59.83	59.60	59.15	59.70	58.70
2002	63.00	61.75	62.33	61.20	60.25	61.75	60.20
5-yr average	61.74	60.97b	61.15a	60.75a	60.62a	61.50b	60.62a
Density (gm/cc)							
1998	1.22	1.25	1.25	1.27	1.30	1.27	1.29
1999	1.26	1.26	1.28	1.28	1.28	1.27	1.29
2000	1.24	1.25	1.26	1.26	1.24	1.25	1.26
2001	1.27	1.26	1.28	1.26	1.28	1.27	1.28
2002	1.24	1.25	1.26	1.28	1.27	1.26	1.27
5-yr average	1.25	1.25b	1.26a	1.27a	1.27a	1.26a	1.28a

Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

* Values in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

between the different treatments on soybean moisture content. The PM treatment effects were significantly different from that of the PM2 treatment, with the PM2 treatment resulting in the highest soybean moisture. The UAN treatment effects are not significantly different from that of the PM treatment, but were significantly different from the PM2 treatment.

Percent Soybean Oil. The five-year treatment averages for soybean percent oil are given in Table 2.8. These results show that there were no significant differences between any of the treatments on soybean oil contents.

Percent Soybean Protein. The five-year treatment averages for soybean protein contents are given in Table 2.8. These results show that there were no significant differences between any of the treatment on soybean protein contents.

Percent Soybean Fiber. The five-year treatment averages for soybean percent fiber are given in Table 2.8. These results show that there were no significant differences between any of the treatment on soybean fiber contents.

Percent Soybean Carbohydrates. The five-year treatment averages for soybean carbs are given in Table 2.8. These results show that there were no significant differences between any of the treatment effects on soybean carbs.

Conclusions

This six-year study was conducted to compare the effects of the four nitrogen treatments [168 kg N/ha poultry manure (PM), 168 kg N/ha urea-ammonium nitrate (UAN), 336 kg N/ha poultry manure (PM2), and 0 kg N/ha (control)] on corn and soybean yields and grain quality, and corn stalk N.

Table 2.8. Field plot soybean grain quality (1998-2002).

Year	Check#	UAN	PM	PM2
Moisture (%)				
1998	6.80	8.85	7.03	10.10
1999	7.20	7.03	7.07	7.00
2000	11.10	10.67	10.80	11.20
2001	12.40	11.23	12.30	10.95
2002	6.60	6.53	6.57	6.53
5-yr average	8.82ac*	8.86bc	8.75b	9.16a
Protein (%)				
1998	35.80	35.65	35.70	35.40
1999	36.30	36.13	36.03	35.97
2000	37.00	37.13	36.90	38.20
2001	33.20	32.98	33.93	33.85
2002	12.40	11.23	12.30	10.95
5-yr average	30.94a	30.62a	30.97a	30.87a
Oil (%)				
1998	18.80	18.13	18.13	18.00
1999	16.40	16.28	16.43	16.33
2000	18.10	18.20	17.90	17.10
2001	18.80	18.95	18.43	18.55
2002	15.80	16.13	16.13	16.23
5-yr average	17.58a	17.54a	17.41a	17.24a
Fiber (%)				
1998	4.90	4.98	5.03	4.87
1999	5.30	5.43	5.33	5.40
2000	5.10	4.93	4.90	5.00
2001	5.00	5.28	5.10	5.20
2002	4.90	5.00	5.07	5.07
5-yr average	5.04a	5.12a	5.09a	5.11a
Carbs (%)				
1998	---♣	---	---	---
1999	24.00	24.18	24.20	24.30
2000	21.80	21.73	22.30	21.70
2001	25.00	24.80	24.53	24.40
2002	23.20	22.98	23.53	23.17
5-yr average	23.50a	23.42a	23.64a	23.39a

Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

* Values in the same row followed by the same letter are not significantly different at significance level of P = 0.05. ♣ --- means no data.

Table 2.9. Five year average for crop yields, corn stalk N, and grain quality (1998-2003).

Parameters	Field Plots				Lysimeters		
	Check*	UAN	PM	PM2	UAN	PM	PM2
Crop Yields							
Corn (kg/ha)	5339	8785b¶	9860ab	10045a	5297b	6146b	8982a
Soybeans (kg/ha)	2537	2961a	3333a	3391a	---♣	---	---
Corn Stalk N (ppm)	27	1406b	1391b	4565a	235a	28a	154a
Corn Grain Quality							
Moisture (%)	14.00	13.13b	13.52ab	13.68a	11.33a	11.57a	11.79a
Protein (%)	6.40	7.42b	7.19b	7.71a	8.50a	7.07a	8.30a
Oil (%)	3.36	3.29b	3.44a	3.40a	3.21a	3.39b	3.22a
Starch (%)	61.74	60.97b	61.15a	60.75a	60.62a	61.50b	60.62a
Density (gm/cc)	1.25	1.25b	1.26a	1.27a	1.27a	1.26a	1.28a
Soybean Grain Quality							
Moisture (%)	8.82	8.86b	8.75b	9.16a	---	---	---
Protein (%)	30.94	30.62a	30.97a	30.87a	---	---	---
Oil (%)	17.58	17.54a	17.41a	17.24a	---	---	---
Fiber (%)	5.04	5.12a	5.09a	5.11a	---	---	---
Carbs (%)	23.50	23.42a	23.64a	23.39a	---	---	---

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of $P = 0.05$. ♣ – means no data.

This study resulted in the following conclusions:

i) The poultry manure applied plots resulted in higher corn and soybean yields in comparisons with the plots receiving UAN N-applications at similar rates.

ii) The corn stalk N concentrations from field plots receiving 336 kg N/ha application of poultry manure were significantly higher in comparison to plots receiving UAN and poultry manure at rates of 168 kg N/ha.

iii) The data on grain quality parameters gave strong evidence that grain moisture, protein, and oil content were found to be higher in poultry manure applied plots in comparison with the UAN fertilizer plots. *iv*) The overall results of this study indicate that poultry manure applied at a rate of 168 kg N/ha would be a good management practice from sustainability perspectives.

References

Beyer, Scott R. Revised 2002. *Frequently Asked Questions About Poultry*. Kansas State University Research and Extension. Publication not numbered. http://www.oznet.ksu.edu/poultry/faq.htm#E.%20Layers (Date accessed: November 19, 2003)

Blackmer, A.M. and A.P. Mallarino. Sept. 2000. *Cornstalk testing to evaluate nitrogen management*. University Extension, Iowa State University. Publication PM1584. http://www.extension.iastate.edu/Publications/PM1584.pdf (Date accessed: November 19, 2003)

Blanchet, L. 1996. Impact of lime application on transport of nitrate-nitrogen, atrazine, and cyanazine to subsurface drainage water: A lysimeter study. MS thesis. Ames, Iowa: Iowa State University.

Chinkuyu, Adion. 2000. Environmental impacts of the use of poultry manure for agricultural production systems. PhD dissertation. Ames, Iowa: Iowa State University.

Chinkuyu, Adion, R.S. Kanwar, J.C. Lorimor, H. Xin, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. *Transactions of the ASAE* 45(2): 299-308.

Hach Company, 1997. *Water Analysis Handbook.* 3rd ed. Hach Company, Loveland, CO.

Kanwar, R.S., J.L. Baker, and D.G. Baker. 1988. Tillage and split N-fertilization effects on subsurface drainage water quality and crop yields. *Trans. ASAE* 31(2): 453-461.

Killorn, Randy and Jeff Lorimor. 1999. *Managing Manure Nutrients for Crop Production.* University Extension, Iowa State University. Publication PM1811. http://www.extension.iastate.edu/Publications/PM1811.pdf (Date accessed: November 19, 2003)

National Atlas of the United States, December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

Schwantz, Lee. 1979. "Feeding Instructions." Farmer's Digest. Wisconsin. (Referenced from *The Family Poultry Flock*) Website: *CHICKEN FEED: The* World of Chickens http://www.lionsgrip.com/feedinstruc.html (Date accessed: November 19, 2003)

Soil Conservation Service. 1992. *National Engineering Handbook: Agricultural Waste Management Field Handbook.* United States Department of Agriculture.

Soil Survey Division (SSD), Natural Resources Conservation Service, United States Department of Agriculture. *Official Soil Series Descriptions* [Online WWW]. Available URL: http://ortho.ftw.nrcs.usda.gov/osd/ (Date accessed: January 3, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 1999. *Agricultural Statistics 1999.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2000. *Agricultural Statistics 2000.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2001. *Agricultural Statistics 2001.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2002. *Agricultural Statistics 2002.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2003. *Agricultural Statistics 2003.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 17, 2003)

U.S. Department of Interior. 2000. *National Atlas of the United States*. December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

U.S. Geological Survey. October 2002. "Cities and Towns", *in National Atlas of the United* States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey. November 2002. "Aquifers of Alluvial and Glacial Origin", *in National Atlas of the United States*. http://nationalatlas.gov. (Accessed: November 19, 2003)

U.S. Geological Survey. January 2002. "Roads", *in National Atlas of the United States*. http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey. July 2002. "States", *in National Atlas of the United States*. http://nationalatlas.gov. (Date accessed: November 19, 2003)

CHAPTER 3. EFFECTS OF POULTRY MANURE ON SURFACE AND SUBSURFACE DRAINAGE WATER QUALITY

A paper to be submitted to the Journal of American Water Resources Association (JAWRA)

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Abstract

A six-year study was conducted to determine the effects of poultry manure on water quality and crop growth parameters. Eleven experimental plots were used for this study. Three experimental treatments were used to give N applications at rates of: *i*) 168 kg N/ha from poultry manure (PM), *ii*) 168 kg N/ha from urea-ammonium nitrate (UAN), and, *iii*) 336 kg N/ha from poultry manure (PM2). Each of these treatments were replicated three and four times using ten of the eleven plots. The eleventh plot was used as a check plot with zero application of nitrogen or poultry manure. These field plots were planted to a corn-soybean rotation. In addition, six lysimeters (2.29m x 0.91m x 1.52 m) were also used for this study. The results of this indicate that the poultry manure giving an application of 168 kg N/ha resulted in lower NO_3-N concentrations in subsurface drainage water and higher crop yields in comparison to UAN and PM2 nitrogen applications. Also, the 168 kg N/ha application from poultry manure resulted in reduced total NO_3-N losses with subsurface drainage water as compared to the UAN and PM2 treatments. These results clearly show that if poultry manure is applied at nitrogen rates (of 168 kg N/ha), farmers could expect better crop yields, reduced NO_3-N concentrations in subsurface drain water, and possibly better soil quality.

Key Terms: poultry manure, field plots, lysimeters, corn soybean rotation, continuous corn, water quality, NO_3-N, PO_4-P, agricultural hydrology

Introduction

Iowa's egg industry continues to grow each year. In 2001 Iowa became the number one egg producing state in the US, producing 8.69 billion eggs (USDA-NASS, 2002). In 2002, Iowa broke its record producing 9.91 billion eggs, thus maintaining its position as number one egg producing state for 2002 (USDA-NASS, 2003) (Table 3.1). In order for Iowa to continue producing such a high number of eggs, an average of 675 million pounds of feed per year would be required leading to the generation of some 817 million pounds of manure per year (Beyer, 2002; Schwantz, 1979; SCS, 1992; USDA-NASS, 2003) (This does not include waste from other chicken types such as broilers etc.) (Table 3.2). With so much poultry manure being generated every year brings the need to find ways to manage this manure so that it does not create environmental problems. The most common way of utilizing manure is to apply it on fields to help add valuable nutrients for growing crops. Unfortunately, the amount of nutrients present in the manure typically is not present in the same ratios as are needed by the crops to be grown. This can result in the over application of some nutrients especially phosphorus leading to water quality problems. To help solve water quality problems, policies were developed in Iowa on how much manure could to be applied to fields based on the nitrogen requirements of the crops. Over time the excess phosphorus builds up in the soil and is washed off from fields into runoff and subsurface tile flow. This can lead to other water quality problems. Thus, other methods of nutrient management were needed in order to reduce the high phosphorus levels that had become prevalent in soils that were being overly applied with manure and to prevent phosphorus losses from fields to Iowa's water bodies.

Table 3.1. Iowa's egg industry statistics for the years 1998-2002.

Year	Rank	No. of eggs produced	Average No. of Layers	Rate of Egg Laying Per Year Per Hen
1998	4th	5,969,000,000	23,044,000	259
1999	2nd	6,754,000,000	25,623,000	264
2000	2nd	7,554,000,000	28,098,000	269
2001	1st	8,691,000,000	32,591,000	267
2002	1st	9,910,000,000	36,980,000	268

*Information from the USDA National Agricultural Statistics Service (USDA-NASS, 2003, 2002, 2001, 2000, 1999)

Table 3.2. Calculations for feed use and waste production by laying hens.

Assumptions:

1 Iowa has an average of 36,980,000 layer hens in 2002 (NASS, 2002)
Each layer hen produce 268 eggs per year
Iowa produced 9,910,000,000 eggs in 2002

2 Layer hen cycle = 12 months (Beyer, 2002)

3 0.5 lb of 15% protein feed given per 10 hens per day (Schwantz, 1979)

4 60.5 lb manure/1000 layer hens is produced each day having a volume of 0.93 ft^3 manure/1000 hens/day (value is manure as excreted with moisture being 75% of total wt) (SCS, 1992)

Amount of feed needed to supply Iowa layer hens in a year 2002.

$$36{,}980{,}000 \text{ hens} * \frac{0.5 \text{ lb feed}}{10 \text{ hens} * \text{day}} * \frac{365 \text{ days}}{1 \text{ year}} = \mathbf{\frac{674{,}885{,}000 \text{ lb feed}}{\text{year}}}$$

Amount of manure generated by Iowa layer hens in 2002.

$$36{,}980{,}000 \text{ hens} * \frac{60.5 \text{ lb manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{816{,}610{,}850 \text{ lb manure}}{\text{year}} = \mathbf{\frac{816{,}611{,}000 \text{ lb manure}}{\text{year}}}$$

$$36{,}980{,}000 \text{ hens} * \frac{0.93 \text{ ft}^3 \text{ manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{12{,}552.861 \text{ ft}^3 \text{ manure}}{\text{year}} = \mathbf{\frac{12{,}553{,}000 \text{ ft}^3 \text{ manure}}{\text{year}}}$$

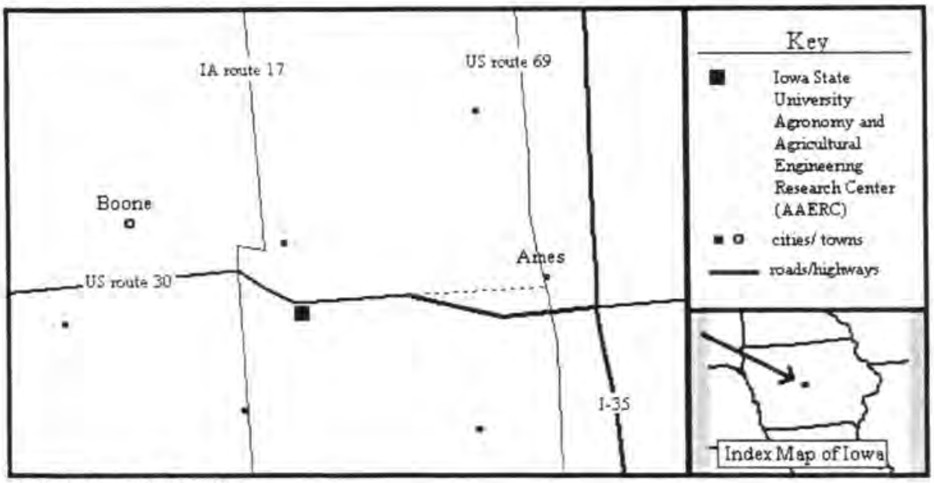
A six-year study was conducted (from 1998 through 2003) in order to better understand how poultry manure applied to field plots impacts crop growth, soil nutrients, and water quality. Specifically, the questions being addressed in this study were: *i*) what was optimum application of poultry manure to obtain high corn and soybean yields and *ii*) what are the effects of poultry manure on NO_3-N and PO_4-P concentrations in surface runoff and subsurface drainage water. Therefore, three experimental treatments were used in this study, to apply poultry manure at rates to give 168 kg N/ha and 336 kg N/ha, and to apply UAN fertilizer rates of 168 kg N/ha.

Materials and Methods

Site Location and Experimental Units

This study was conducted in Field 5 at the Iowa State University Agronomy and Agricultural Engineering Research Center located on US highway 30 between Ames and Boone, Iowa (Figure 3.1). The soils in Field 5 are a part of the Clarion-Nicollet-Webster soil association (Blanchet, 1996; Chinkuyu et al., 2002; Chinkuyu, 2000). These soils were derived from glacial till laid down during the last glacial retreat that extended throughout an area of Iowa known as the Des Moines lobe advance (SSD, no date; Chinkuyu et al., 2002; Chinkuyu, 2000) [Figure 3.2]. Originally, these soils yielded prairie vegetation before being converted to productive farmland (Chinkuyu et al., 2002; Chinkuyu, 2000) [More information about Field 5 soils can be obtained in Appendix A.].

Within field 5 are the eleven field plots that were used in this experiment. The field plots, as shown in Figure 3.3, vary in size from 0.19 ha (0.47 ac) to 0.42 ha (1.04 ac). These



National Atlas of the United States

Figure 3.1 Location of Agronomy and Ag. Engineering Research Farm in relation to Ames, and Boone.

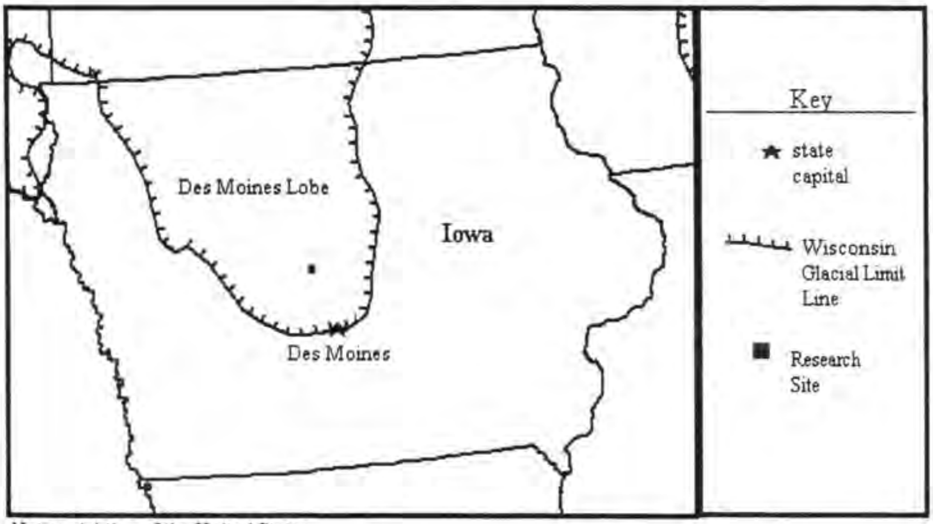


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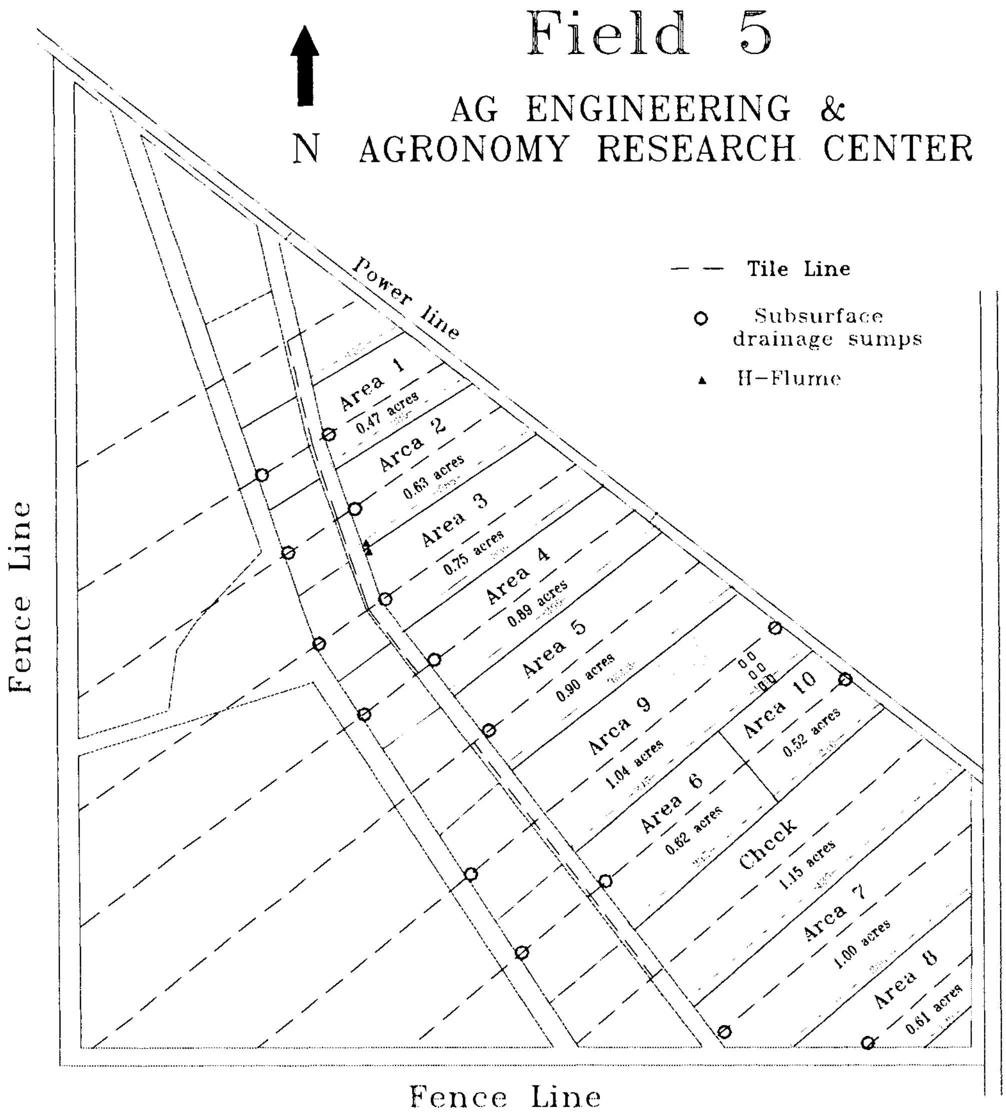
Figure 3.2. Extent Des Moines Lobe Glacial Advance.



1 336 kg-N/ha Poultry Manure
2 168kg-N/ha Poultry Manure
3 336 kg-N/ha Poultry Manure
4 168 kg-N/ha UAN Fertilizer
5 168 kg-N/ha Poultry Manure
6 168 kg-N/ha UAN Fertilizer
7 336 kg-N/ha Poultry Manure
8 168 kg-N/ha UAN Fertilizer
9 168 kg-N/ha UAN Fertilizer
10 168 kg-N/ha Poultry Manure
Check Plot ; No Poultry Manure or UAN Fertilizer

Figure 3.3. Field Plots in Field 5.

field plots were established in 1984 and plot is drained by a single subsurface tile drain through the center of the plot and is intercepted by a sump containing monitoring devices for measuring water flow and collecting samples for water quality analysis (Kanwar et al., 1988; Blanchet, 1996). The sump for the control (check) plot was not installed until fall 1999.

The six lysimeters are located within field plot 9 (Figure 3.4). Constructed in 1992, the lysimeters are arranged in two rows of three with each lysimeter being 381 cm (12.5 ft) apart from each other (Figure 3.5). First, the containers to hold the soil profiles were assembled. Each container consists of three layers: an outer polyethene plastic layer, a middle Styrofoam layer, and an inner plastic liner (Figure 3.6). Then, using a grave-digging machine, the soil profiles that would be used to fill the lysimeter containers, were removed in 15 and 30 cm deep layers, in such a way, that the profile could be reassembled when the soil would be put in the containers. Once the soil was removed, four soil core samples were taken from the walls in each of the four sides of the holes and tested for hydraulic conductivity, bulk density, and other soil properties, which are given in Blanchet (1996). Then a Bentonite (clay) layer was added to the bottom of the holes before the containers were lowered into them. Afterwards, more Bentonite was used to fill in the space between the lysimeter containers and the walls of the hole. Then, the sump and tile system was installed inside to the lysimeters before finally packing the soil layers into the lysimeters (Figure 3.6). Care was taken to reassemble the original soil profiles. More details on the construction and installation of the lysimeters are given in Blanchet (1996).

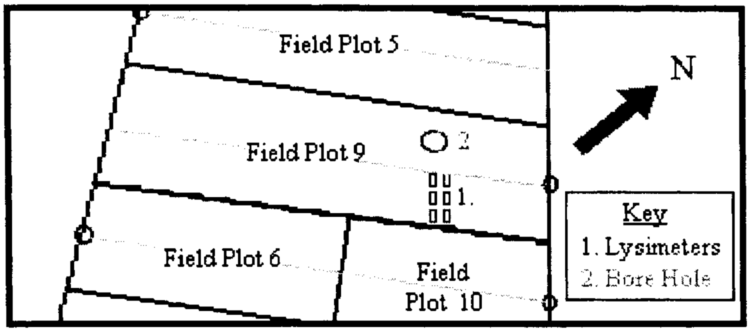


Figure 3.4. Location of Lysimeters.

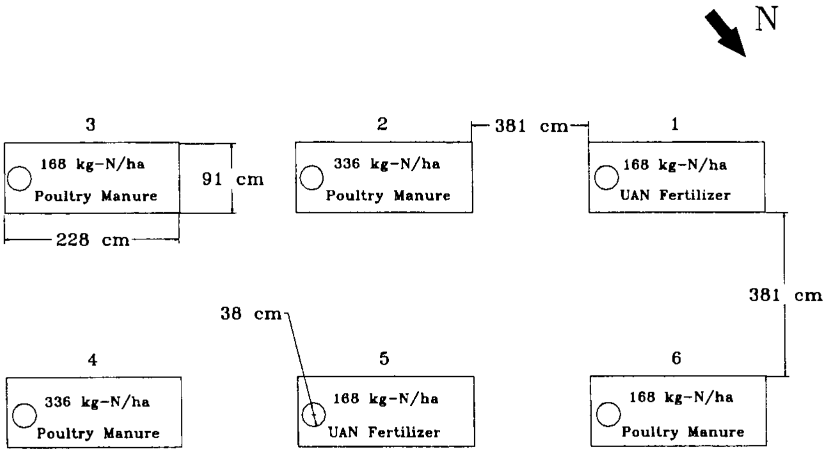


Figure 3.5. Layout of lysimeters to study the effects of N management systems on subsurface drainage water quality.

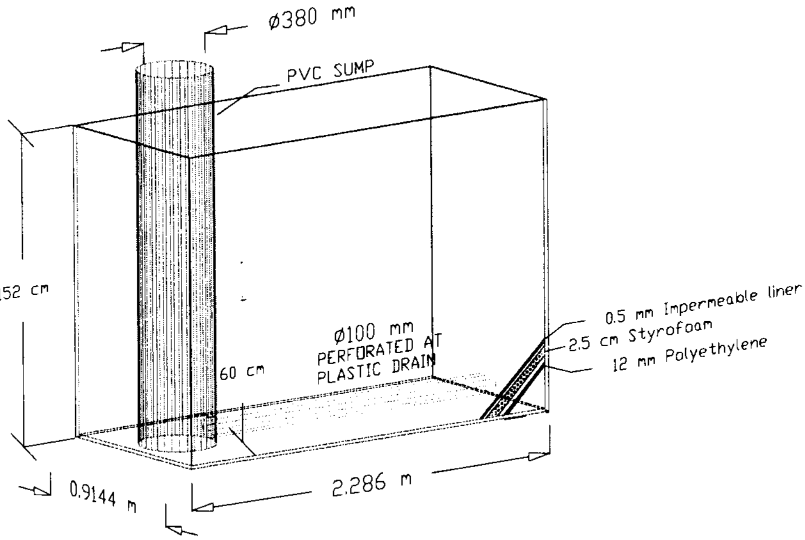


Figure 3.6. Design details of lysimeter construction box to study the effects of N management systems on subsurface drainage water quality.

Experimental Treatments

Manure/Fertilizer Applications

Laying hen poultry manure used in this experiment was obtained from a laying hen farm located in Humboldt, Iowa. Prior to applying the poultry manure to the field plots and lysimeters, samples of the manure were taken and sent to MVTL Laboratories, Inc., located in Nevada, Iowa, to test for total moisture, total nitrogen, phosphorus, potassium, and ammonia-nitrogen. Results from the analysis are given in Table 3.3.

Field Plot. The following treatments were applied on the field plots: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), *iii*) 336 kg N/ha from poultry manure (PM2), and *iv*) 0 kg N/ha (control treatment). These treatments were randomly assigned to each field plot, but due to the number of field plots available, the treatments were unbalanced with the UAN treatment having four replicates, PM treatment having three replicates, the PM2 treatment having three treatments, and the control treatment having one replicate. Figure 3.3 shows which field plots received what treatment.

The manure was applied to the field plots by surface broadcast on one half of the plots, which are planted in corn. The other half of each field plot that was planted to soybeans received no manure or N fertilizer. After manure or UAN fertilizer was applied to the field plots, it was incorporated into the soil that day or the day after by tilling/disking the soil down to a depth of about 15 cm (6 inches). This was done to help minimize N losses through volatilization (Chinkuyu et al., 2002; Chinkuyu, 2000).

Lysimeters. The following treatments were applied on the lysimeters: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM),

Table 3.3. Characteristics of poultry manure applied to field plots and lysimeters.

Characteristics	1998	1999	2000	2001	2002	2003
Field Plots						
	168 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.49	3.04	2.69	2.16	1.41	2.03
Ammonia (NH_3), %N	1.00	4.37	3.94	2.72	2.24	1.60
Total Phosphorus, %P	1.43	2.29	2.41	20.62	1.20	1.81
Potassium, %K	1.11	0.74	0.72	8.50	0.57	1.71
Moisture Content, %H_2O	48.12	45.03	32.60	56.97	53.70	76.25
	336 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.51	2.98	3.73	2.16	1.41	2.03
Ammonia (NH_3), %N	0.94	4.21	3.76	2.72	2.24	1.60
Total Phosphorus, %P	1.25	1.86	2.25	20.62	1.20	1.81
Potassium, %K	1.06	0.82	0.78	8.50	0.57	1.71
Moisture Content, %H_2O	46.88	54.60	32.23	56.97	53.70	76.25
Lysimeters						
	168 kg N/ha and 336 kg N/ha Poultry Manure Treatments					
Total Kjedhal N (TKN), % N	1.49	2.98	3.80	6.08	1.06	2.03
Ammonia (NH_3), %N	1.00	4.21	3.73	2.10	3.29	1.60
Total Phosphorus, %P	1.43	1.86	2.37	1.28	1.43	1.81
Potassium, %K	1.11	0.82	0.66	1.32	0.45	1.71
Moisture Content, %H_2O	48.00	55.00	27.90	56.90	58.20	76.25

*Conversion for nutrients: % *20 = lbs/ton

and *iii*) 336 kg N/ha from poultry manure (PM2). The treatments were randomly assigned to the lysimeters, giving a total of two replicates per treatment as listed in Figure 3.5. A control treatment was not used for the lysimeters due to the number of lysimeters available for this study (Chinkuyu et al., 2002).

The manure or UAN fertilizer was applied to the lysimeters by hand. First a shovel was used to break up the soil in each lysimeter bed. Then, using a portable balance, the proper amount of manure/fertilizer was weighted on the bases of nitrogen content of the manure/fertilizer being used in a given year. Manure/fertilizer was spread over the surface of each lysimeter, and using the shovel was incorporated into the soil that same day (Chinkuyu et al., 2002). Even though the intended application rates applied to both field plots and lysimeters were based on the nitrogen treatments UAN, PM, and PM2, "the actual amounts of N applied to the plots and lysimeters were different from the desired N application rates because the N content in the manure (determined at the beginning) used in the calibration of the manure spreader was different from the N content determined at the time of application" (Chinkuyu et al., 2002; Chinkuyu, 2000). The actual N application rates averaged PM = 170 kg N/ha and PM2 = 321 kg N/ha for the field plots and PM = 254 kg N/ha and PM2 = 508 kg N/ha for the lysimeters as shown in Table 3.4.

Planting

The field plots were planted to a corn-soybean rotation in such a way that both corn and soybeans are planted on the same field plot in the same year. Using the center tile drain in the middle of each field as a dividing line, one half of the field plot was planted to corn and the other half was planted to soybeans. In even years, like 1998, corn

Table 3.4. Average manure application rates for field plots and lysimeters (1998-2003).

	168 kg N/ha poultry manure				336 kg N/ha poultry manure			
	Average manure application rate, kg/ha	Average application rate, kg/ha*			Average manure application rate, kg/ha	Average application rate, kg/ha*		
		N	P	K		N	P	K
Field Plots								
1998	10674	159	107	152	24190	364	227	303
1999	9575	291	418	220	14774	440	622	275
2000	3213	86	126	78	8741	326	329	196
2001	8998	195	244	1855	14957	324	406	3083
2002	7982	113	179	96	14295	202	320	172
2003	11318	229	181	205	18231	369	292	330
6-yr average	8627	179	209	434	15865	337	366	727
Lysimeter								
1998	15717	234	157	225	31720	473	317	454
1999	2902	86	122	54	5804	173	244	108
2000	2190	83	82	52	4379	166	163	104
2001	10189	620	214	130	20378	1239	428	261
2002	9182	97	302	131	18382	195	605	263
2003	9179	186	147	166	18359	372	294	333
6-yr average	8226	218	171	126	16504	436	342	254

* Assumed 5% N, P, and K lost during application; 75% N, P, and K available during the first year. In subsequent years no credit was given for residual N, P, and K from the manure or N from soybeans.

¶ Intended N application rates from layer manure were 168 kg-N/ha and 336 kg-N/ha, however, actual N application rates averaged PM = 179 kg-N/ha and PM2 = 337 kg-N/ha for the plots; PM = 218 kg-N/ha and PM2 = 436 kg-N/ha for the lysimeters.

was planted on the northern half of the fields and soybeans on the southern half. Then in the following year (an odd year, like 1999), corn was planted on the southern half of the fields and the soybeans on the northern half. The corn variety Dekalb 580 and soybean variety Kruger 2426 were used in the experiment with each being planted at a spacing of 0.75 m between rows and 0.2 m between plants within each row (Chinkuyu et al., 2002; Chinkuyu, 2000).

The lysimeters were planted to continuous corn using Dekalb 580 corn variety. Twelve corn seeds were evenly planted in each lysimeter bed in three rows of four (0.75 m between rows and 0.2 m between plants within each row) (Chinkuyu et al., 2002; Chinkuyu, 2000). If the planted corn seeds did not grow or field rodents ate the seeds, corn plants from the adjacent field plot were dug up and transplanted into the lysimeter beds in order to maintain a population of twelve plants in each lysimeter.

Methods used in the harvesting and grain quality analysis for field plots and lysimeters are given in Chapter 2 of this thesis.

Tillage

Once the field plots had been harvested, the side of each field plot that had corn for that year was tilled using a chisel plow which allows about 30% of the crop residue to remain on the surface of the soil. The side of each field plot that was planted in soybeans did not receive the fall tillage.

Water Sample Collection and Laboratory Analysis

Data on subsurface drain flow rates and surface runoff were collected from the plots as soon as the subsurface drains started flowing in spring or whenever there was a runoff event.

Field Plots. Tile flow in each field plot was measured using a flow meter, which records the amount of water in the sump that is pumped to the outflow tile. The meters were checked weekly and after major rain events. For every gallon of water pumped to the outflow out flow tile, a small fraction of water was sampled and stored in a glass collection bottle using an automated sampling system. From this collection bottle, two water samples per field plot were collected using 125 mL plastic bottles, for NO_3-N and PO_4-P analysis. These samples were acidified by adding 2 drops of sulfuric acid prior to the storage of samples in a 4 degree C cooler. Details on the construction of the sumps and subsurface drain water sampling procedures are given by Kanwar et al., 1988.

For surface runoff measurements, two plots were instrumented with ISCO flow meters on H-flumes to automatically measure surface runoff and collect surface runoff water samples for water quality analysis. These H-flumes were installed in plots having two different N application rates from poultry manure only. The UAN application plots were not sampled for surface runoff for lack of funding.

Lysimeters. Subsurface drainage flow for each lysimeter was determined by pumping out the subsurface drainage water into a calibrated bucket. During the pumping of the lysimeters, two water samples per lysimeter were collected in 125 mL plastic bottles, acidified using sulfuric acid, and stored in a cooler at 4 degrees C until they were analyzed for NO_3-N and PO_4-P concentrations.

NO_3-N and PO_4-P Determinations: Water samples for NO_3-N concentrations in drainage water were analyzed using an automated Technicon Autoanalyer II. Water samples were analyzed for PO_4-P using the Phosphomolybdate Ascorbic Acid method (Hach Co.,

1997) in the Water Quality Laboratory of the Agricultural and Biosystems Engineering Department at Iowa State University (Chinkuyu, 2000).

Results

Statistical Design

The data obtained from this study were tested using a split plot design model and SAS version 8.2. First the data was tested using an F test. If the results indicated that there were significant differences in the treatments, a Student t-test was performed to indicate the significance levels between the treatments. All tests were conducted using an alpha of 0.05. For field plot drainage flow, nutrient concentrations, and flow nutrient losses, the control treatment was not included in the statistical analysis due to there being only one replication for the treatment and due to the lack of three out of six years (1998-2000) of flow data collected. For field plot runoff data, no statistical analysis were conducted because of only one replicate for each of the treatments.

Treatment Effects on Subsurface Drainage Water Quality and Flow Volumes

Subsurface Drainage Flows. The data six-year average subsurface drainage flows for field plots are given in Table 3.5. These data indicate that no significant differences in subsurface drainage flow volumes were observed except in 1998 and 1999. In 1998 and 1999, the PM treatment resulted in significantly lower subsurface drainage flow volumes compared to the UAN treatment. Numerically, the control treatment plot gave the highest subsurface drainage flow among all the treatments primarily because of very low evapo-transpiration demands.

Table 3.5. Field plot flow from subsurface drainage and runoff water (1998-2003).

Year	Month	Subsurface Drainage Flow (cm)				Runoff Flow (cm)	
		Check*	UAN	PM	PM2	PM	PM2
1998	March	---§	0.46	0.46	0.01	---	---
	April	---	1.89	3.54	4.34	---	---
	May	---	3.17	2.19	4.01	0.45	0.65
	June	---	11.51	7.53	9.84	1.05	1.13
	July	---	5.99	3.50	2.78	0.68	0.66
	August	---	---	---	---	0.36	0.43
	Total	---	23.02b¶	17.22a	20.97ab	0.64	0.72
1999	April	---	5.37	3.43	4.27	---	---
	May	---	4.75	4.06	5.05	---	---
	June	---	7.55	3.96	4.93	2.46	1.6
	July	---	0.64	0.60	0.64	---	---
	August	---	0.32	0.33	0.34	0.25	0.21
	Total	---	18.63b	12.38a	15.23ab	0.54	0.36
2000	May	---	0.36	0.14	0.15	---	---
	June	---	0.82	0.16	0.72	---	---
	July	---	0.03	0.03	0.02	---	---
	Total	---	1.02a	0.26a	0.89a	---	---
2001	March	0.00	0.03	0.01	0.00	---	---
	April	0.91	0.04	0.04	0.38	---	---
	May	8.77	3.61	1.56	2.52	---	---
	June	3.90	2.21	1.70	2.09	---	---
	July	0.48	0.06	0.04	0.02	---	---
	Total	14.06	5.95a	3.34a	5.01a	---	---
2002	May	7.99	3.71	3.09	3.94	---	---
	June	3.38	0.79	1.17	1.67	---	---
	July	2.86	0.49	0.37	0.52	---	---
	August	1.74	0.34	0.21	0.35	---	---
	Total	15.96	5.32a	4.84a	6.49a	---	---
2003	May	11.22	8.30	6.42	7.65	---	---
	June	1.66	0.38	1.03	1.08	---	---
	July	4.47	4.26	4.94	4.79	---	---
	Total	17.35	12.94a	12.40a	13.51a	---	---
6-yr average		15.79	11.15b	8.41a	10.35ab	0.59	0.54

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. § – means no data.

The data on six-year average subsurface drainage flow amounts for lysimeters are given in Table 3.6 and show that there were no significant differences between the treatment effects.

Runoff volumes. The six-year average runoff flow volumes for field plots under the two poultry manure nitrogen treatments are given in Table 3.5. Although no statistical analysis was performed on these data, numerically, the PM treatment resulted in higher runoff flow volumes compared to the PM2 treatment.

Treatment Effects on NO_3-N Concentrations in Subsurface Drainage and Runoff Water

The six-year average NO_3-N concentrations in subsurface drainage water for field plots are given in Table 3.7. These results show that for some years significant differences among the treatments were observed. The overall six-year average NO_3-N concentration data indicate that the PM2 treatment resulted in significantly higher NO_3-N concentrations of 27.52 mg/L in subsurface drain water in comparison to the PM treatment of 17.39 mg/L and UAN treatment of 19.49 mg/L. Also, for all six individual years, the PM2 treatment resulted in higher NO_3-N concentrations in subsurface drainage water from field plots. The PM2 treatment is significantly different from the UAN and PM treatments, with the PM2 NO_3-N concentration being the highest of the three treatments. The UAN and PM treatments are not significantly different from each other. Numerically, the control NO_3-N concentration is the lowest of all the treatments.

The six-year NO_3-N concentration averages for lysimeters under the three nitrogen rates are given in Table 3.8. These results in Table 3.8 show that the PM2 treatment resulted

Table 3.6. Lysimeter flow from subsurface drainage water (1998-2003).

Year	Month	Subsurface Drainage Flow		
		UAN*	PM	PM2
		Flow (cm)		
1998	May	1.90	1.25	1.70
	June	22.10	20.60	19.86
	July	3.95	2.45	3.00
	Total	27.95a¶	24.30a	24.56a
1999	April	7.84	6.15	6.47
	May	9.30	7.50	10.49
	June	12.91	12.47	13.96
	July	3.11	2.08	2.92
	August	1.06	1.11	1.18
	Total	34.21a	29.30a	35.01a
2000	May	2.35	2.65	2.55
	June	4.30	4.65	5.95
	July	0.50	0.50	0.80
	Total	7.15a	7.80a	9.30a
2001	May	25.27	25.17	26.28
	June	5.47	4.52	4.27
	July	0.49	0.35	0.33
	Total	31.23a	30.05a	30.88a
2002	May	15.51	13.36	15.49
	June	3.18	3.33	3.35
	July	3.71	2.85	2.68
	August	2.06	1.24	0.00
	Total	24.46a	20.78a	21.52a
2003	April	5.89	7.54	4.69
	May	13.24	12.54	12.73
	June	4.07	3.78	5.17
	July	9.67	8.90	9.29
	Total	32.86a	32.77a	31.88a
6-yr average		26.31a	24.17a	25.53a

* UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

Table 3.7. Flow weighted average monthly and yearly NO_3-N concentrations in subsurface drainage and surface runoff water from field plots (1998-2003).

Year	Month	Subsurface Drainage Flow				Runoff Flow	
		Check*	UAN	PM	PM2	PM	PM2
		NO_3-N Concentration (mg/L)					
1998	March	---§	13.25	9.40	14.15	---	---
	April	---	17.15	12.52	17.72	---	---
	May	---	18.55	13.70	16.56	13.11	13.23
	June	---	21.01	18.25	23.36	14.67	15.13
	July	---	19.24	15.86	20.46	16.32	17.50
	August	---				11.11	11.63
	Yr-Average	---	17.84a¶	14.35a	19.07a	14.22	14.72
1999	April	---	18.98	18.72	26.99	---	---
	May	---	22.69	24.63	30.49	---	---
	June	---	22.63	22.12	28.58	3.54	5.56
	July	---	21.13	14.16	25.03	---	---
	August	---	11.76	8.43	11.87	3.20	4.29
	Yr-Average	---	19.24a	18.55a	25.40a	3.52	5.56
2000	May	---	26.97	16.81	51.23	---	---
	June	---	22.41	16.97	48.00	---	---
	July	---	23.50	---	12.10	---	---
	Yr-Average	---	22.78ab	16.89b	37.11a	---	---
2001	March	---	0.00	0.00	18.60		
	April	3.63	11.52	16.15	14.96	---	---
	May	7.97	18.12	23.10	42.60	---	---
	June	9.24	21.75	22.12	33.85	---	---
	July	9.47	24.93	24.93	31.35	---	---
	Yr-Average	7.58	18.23b	21.98b	32.77a	---	---
2002	May	10.14	22.48	20.55	34.48	---	---
	June	7.69	21.72	20.37	32.33	---	---
	July	5.83	20.57	15.74	20.36	---	---
	August	0.00	0.00	0.00	0.00	---	---
	Yr-Average	5.92	16.19b	14.17b	21.79a	---	---
2003	May	8.74	20.58	16.74	27.23	---	---
	June	9.58	22.96	18.50	29.28	---	---
	July	11.29	24.49	---	30.38	---	---
	Yr-Average	9.87	22.68ab	18.41b	28.96a	---	---
6-yr average		7.79	19.49b	17.39b	27.52a	9.32	11.67

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. § – means no data.

in significantly higher NO_3-N concentrations in comparison with the PM treatment

The six-year data on average runoff NO_3-N concentrations for the two poultry manure treatments are given in Table 3.7. Although no statistical analysis were performed on these the field plot under the PM treatment resulted in lower NO_3-N concentrations in runoff water in comparison with the plot under the PM2 treatment.

Treatment Effects on NO_3-N Losses With Subsurface Drainage Water and Surface Runoff

The six-year average monthly and yearly NO_3-N losses with subsurface drainage water from field plots are given in Table 3.9. These results clearly show that the six-year average NO_3-N loss of 15.43 kg/ha from Pm plots is significantly lower than 28.07 kg/ha from PM2 plots. The NO_3-N losses from UAN and PM treatments were not significantly different from each other although the NO_3-N loss of 15.04 kg/ha from PM plots was much lower in comparison with the NO_3-N loss from UAN plots of 22.97 kg/ha.

The monthly and yearly NO_3-N losses with subsurface drainage water from lysimeters are given in Table 3.10. The results show that there are no significant differences in six-year average NO_3-N losses between treatments although PM2 treatment gave a six-year average NO_3-N loss of 42.10 kg/ha in comparison with the NO_3-N loss of 20.31 kg/ha from PM treatment.

The six-year NO_3-N loss averages from runoff for field plots under the two poultry manure rates are given in Table 3.9. These are very low in comparison to the NO_3-N losses with subsurface drain water. On a numerical basis, the PM2 treatment effects on resulted in higher NO_3-N losses in comparison with the PM treatment.

Table 3.8. Flow weighted average monthly and yearly NO_3-N concentrations in subsurface drainage and surface runoff water from lysimeters (1998-2003).

Year	Month	Subsurface Drainage Flow		
		UAN*	PM	PM2
		NO_3-N Concentration (mg/L)		
1998	May	10.00	2.00	14.50
	June	16.11	11.17	20.20
	July	21.21	14.23	31.12
	Total	16.45ab¶	10.99b	21.13a
1999	April	8.62	9.26	20.54
	May	9.56	10.12	18.03
	June	8.20	11.83	13.83
	July	9.44	10.11	11.77
	August	10.05	9.95	14.75
	Total	8.81a	10.76a	16.23a
2000	May	4.37	4.30	9.34
	June	6.86	4.06	10.72
	July	9.53	4.73	11.67
	Total	6.12a	4.17a	10.40a
2001	May	22.34	5.09	12.73
	June	17.62	4.44	8.99
	July	9.08	6.19	6.46
	Total	21.28b	5.01a	12.10a
2002	May	7.51	2.93	8.35
	June	17.49	6.65	10.62
	July	24.59	20.61	23.22
	August	15.58	2.09	---
	Total	11.88a	5.65a	10.53a
2003	April	9.66	1.22	6.29
	May	33.02	7.38	26.41
	June	31.82	12.91	30.20
	July	18.88	19.19	24.38
	Total	24.51a	9.82b	23.41a
6-yr average		14.84ab	7.73b	15.63a

* UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

Table 3.9. Average monthly and yearly NO_3-N loss with subsurface drainage and runoff water from field plots (1998-2003).

Year	Month	Subsurface Drainage Flow				Runoff Flow	
		Check*	UAN	PM	PM2	PM	PM2
				NO_3-N Loss (kg/ha)			
1998	March	---§	0.65	0.44	0.01	---	---
	April	---	2.78	4.47	8.20	---	---
	May	---	5.66	2.92	6.33	0.59	0.86
	June	---	24.27	13.74	23.08	1.54	1.71
	July	---	11.83	5.68	5.62	1.11	1.16
	August	---	---	---	---	0.40	0.50
	Total	---	45.19a¶	27.25b	43.24a	0.91	1.06
1999	April	---	10.26	6.47	12.54	---	---
	May	---	10.80	10.05	15.26	---	---
	June	---	17.18	8.79	14.81	0.87	0.89
	July	---	1.35	1.03	1.48	---	---
	August	---	0.41	0.32	0.29	0.08	0.09
	Total	---	40.01ab	26.65b	44.38a	0.19	0.20
2000	May	---	0.97	0.24	0.77	---	---
	June	---	1.98	0.46	3.46	---	---
	July	---	0.07	0.00	0.02	---	---
	Total	---	2.50a	0.69a	4.25a	---	---
2001	March	0.00	0.00	0.00	0.00	---	---
	April	0.33	0.05	0.04	0.10	---	---
	May	6.99	6.24	3.08	9.88	---	---
	June	3.61	4.80	3.59	6.95	---	---
	July	0.45	0.16	0.10	0.08	---	---
	Total	11.38	11.24a	6.81a	17.00a	---	---
2002	May	8.10	8.36	6.23	13.77	---	---
	June	2.60	1.69	2.25	5.38	---	---
	July	1.66	0.99	0.53	1.05	---	---
	August	0.00	0.00	0.00	0.00	---	---
	Total	12.36	11.05a	9.00a	20.19a	---	---
2003	May	9.81	16.82	10.60	21.28	---	---
	June	1.59	0.81	1.84	3.38	---	---
	July	5.04	10.23	9.73	14.70	---	---
	Total	16.44	27.86ab	22.17b	39.35a	---	---
6-yr average		13.39	22.97ab	15.43b	28.07a	0.55	0.63

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. § – means no data.

Table 3.10. Average monthly and yearly NO_3-N loss with subsurface drainage and runoff water from lysimeters (1998-2003).

Year	Month	Subsurface Drainage Flow		
		UAN*	PM	PM2
		NO_3-N Loss (kg/ha)		
1998	May	1.91	0.24	2.47
	June	34.95	24.39	40.03
	July	8.18	3.56	9.33
	Total	45.04a¶	28.20a	51.82a
1999	April	6.71	5.81	13.31
	May	8.87	7.61	19.02
	June	10.58	14.92	19.32
	July	2.90	2.08	3.49
	August	1.06	1.11	1.73
	Total	30.12b	31.52ab	56.85a
2000	May	1.09	1.14	2.38
	June	3.19	1.90	6.37
	July	0.51	0.24	0.93
	Total	4.79a	3.28a	9.68a
2001	May	56.28	12.38	33.34
	June	10.10	2.05	3.89
	July	0.45	0.27	0.23
	Total	66.82b	14.69a	37.46a
2002	May	11.79	4.04	12.94
	June	5.57	2.20	3.56
	July	9.05	5.45	6.05
	August	2.46	0.27	0.00
	Total	28.87a	11.96a	22.54a
2003	April	5.56	0.92	3.02
	May	43.71	9.30	33.58
	June	12.91	4.90	15.51
	July	18.27	17.09	22.16
	Total	80.45a	32.21b	74.27a
6-yr average		42.68a	20.31a	42.10a

* UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

Treatment Effects on PO_4-P Concentrations in Subsurface Drainage and Runoff Water

The six-year average monthly and yearly PO_4-P concentrations in subsurface drainage water from field plots under four nitrogen treatments are given in Table 3.11. These results indicate that there are significant differences between some treatments. The PM2 treatment resulted in significantly higher PO_4-P concentrations in subsurface drainage water in comparison with the PO_4-P concentrations from the PM treatment. The PO_4-P concentration from the UAN treatment is not significantly different from PO_4-P concentrations the PM and PM2 treatment effects. Although no phosphorus fertilizer was applied to the UAN plots, these plots had relatively high soil PO_4-P because of continuous application of P-fertilizer since 1969.

The six-year average PO_4-P concentrations in subsurface drainage water from the lysimeters under the three nitrogen treatments are given in Table 3.12. The results indicate that no significant differences were observed between treatment effects on PO_4-P concentrations in subsurface drainage water from the lysimeters.

The six-year average PO_4-P concentrations in runoff water for field plots, under the poultry manure treatments, are given in Table 3.11. Statistics could not be performed on this data due to only one replication per treatment. Although the PM2 treatment resulted in six-year average PO_4-P concentrations in runoff water of 1213 ppb which is much higher than the PO_4-P runoff concentration of 980 ppb in runoff water from PM treatment.

PO_4-P Losses

Subsurface Flow

Field Plots. The six-year averages for field plot PO_4-P losses in subsurface tile drainage are given in Table 3.13. These results show that there are no significant

Table 3.11. Flow weighted average monthly and yearly PO_4-P concentrations in subsurface drainage and surface runoff water from field plots (1998-2003).

Year	Month	Subsurface Drainage Flow				Runoff Flow	
		Check*	UAN	PM	PM2	PM	PM2
		PO_4-P Concentration (μ/L)					
1998	March	---□	0.00	0.00	0.00	---	---
	April	---	2.19	5.18	12.57	---	---
	May	---	18.73	5.79	12.26	1382.2	1010.8
	June	---	17.73	14.10	16.79	1665.7	1690.3
	July	---	7.44	12.73	9.20	1116.2	1998.5
	August	---	---	---	---	480.6	709.3
	Yr-Average	---	9.22a¶	7.98a	11.97a	1290.6	1455.6
1999	April	---	11.60	7.73	20.40	---	---
	May	---	8.42	6.78	17.59	---	---
	June	---	21.16	13.08	37.40	613.8	736.3
	July	---	16.19	14.00	158.74	---	---
	August	---	14.00	18.84	10.22	544.0	604.8
	Yr-Average	---	13.82b	11.27b	38.81a	609.3	725.0
2000	May	---	9.63	8.25	83.68	---	---
	June	---	12.02	10.77	11.76	---	---
	July	---	9.90	---	14.30	---	---
	Yr-Average	---	12.63b	9.51b	36.58a	---	---
2001	March	---	0.00	1.52	0.00	---	---
	April	0.00	0.00	0.00	0.00	---	---
	May	4.97	0.20	0.18	0.80	---	---
	June	2.17	0.32	0.35	0.40	---	---
	July	0.14	0.01	0.01	0.01	---	---
	August	---	---	---	---	---	---
	Yr-Average	1.82	0.17a	0.14a	0.40a	---	---
2002	May	2.16	0.51	0.68	0.70	---	---
	June	3.67	0.37	0.63	1.20	---	---
	July	7.39	0.18	0.95	2.10	---	---
	Yr-Average	4.41	0.35a	0.75a	1.33a	---	---
2003	May	20.30	4.82	2.68	4.31	---	---
	June	1.35	0.16	0.72	0.41	---	---
	July	2.48	0.81	---	4.43	---	---
	Yr-Average	8.04	1.93A	1.59A	3.05A	---	---
6-yr average		4.76	6.35ab	5.21b	15.36a	979.7	1213.0

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. □ – means no data.

Table 3.12. Flow weighted average monthly and yearly PO_4-P concentrations in subsurface drainage and surface runoff water from lysimeters (1998-2003).

Year	Month	Subsurface Drainage Flow		
		UAN*	PM	PM2
		PO_4-P Concentration (μ/L)		
1998	May	296.20	24.45	16.35
	June	116.22	119.88	18.10
	July	152.06	9.74	6.79
	Total	135.08b¶	105.91ab	16.58a
1999	April	60.45	19.12	39.84
	May	27.55	26.34	105.36
	June	15.82	24.30	24.26
	July	17.26	25.92	19.92
	August	356.00	174.00	194.50
	Total	38.95a	29.51a	56.95a
2000	May	17.55	6.85	14.50
	June	30.99	10.24	16.35
	Total	24.81a	8.42a	14.43a
2001	May	16.93	15.21	23.49
	June	6.89	6.55	7.59
	July	7.99	5.61	11.63
	Total	15.17a	13.72a	20.94a
2002	May	2.61	2.28	3.72
	June	7.00	7.45	6.21
	July	10.42	15.08	11.66
	August	11.82	25.39	---
	Total	5.03a	6.09a	5.03a
2003	April	5.80	5.09	7.61
	May	5.95	9.02	10.06
	June	6.78	6.94	4.88
	July	5.17	8.68	5.18
	Total	5.78a	7.77a	7.46a
6-yr average		37.47a	28.57a	20.23a

* UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

differences between the UAN, PM, and PM2 treatment effects on PO_4-P losses. Interestingly, PO_4-P losses from the control treatment were higher than that the PM and UAN treatments but lower than that of the PM2 treatment.

The six-year average PO_4-P losses with subsurface drainage from lysimeters are given in Table 3.14. These results indicate that there are no significant differences on PO_4-P losses with subsurface drainage water between the treatments.

The six-year average PO_4-P losses with runoff water from field plots under the poultry manure treatments are given in Table 3.13. Although no statistical tests could be performed because of lack of replications per treatment, the PO_4-P losses from the PM treatment were less compared with the PM2 treatment.

Discussion

Effects of Poultry Manure on NO_3-N Concentrations in Subsurface Drainage and Runoff Water

Subsurface Drainage. The data in Table 3.15 shows clearly that the NO_3-N concentrations in subsurface drainage water were significantly lower in comparison to the UAN and PM2 treatments. This shows that NO_3-N concentrations in subsurface drain water can be managed by using appropriate application rates of poultry manure.

For lysimeters, it can be seen from the data in Table 3.15 that the UAN and PM2 treatment resulted in significantly higher NO_3-N concentrations in subsurface drainage water in comparison with the PM treatment. Again, these results from lysimeters indicate that appropriate application rates of poultry manure can result in improved water quality.

Table 3.13. Average monthly and yearly PO_4-P loss with subsurface drainage and runoff water from field plots (1998-2003).

Year	Month	Subsurface Drainage Flow				Runoff Flow	
		Check*	UAN	PM	PM2	PM	PM2
		PO_4-P Loss (kg/ha)					
1998	March	---□	0.0000	0.0000	0.0000	---	---
	April	---	0.0008	0.0020	0.0042	---	---
	May	---	0.0052	0.0013	0.0064	0.0622	0.0657
	June	---	0.0205	0.0106	0.0166	0.1749	0.1910
	July	---	0.0052	0.0052	0.0025	0.0759	0.1319
	August	---	---	---	---	0.0173	0.0305
	Total	---	0.0317a¶	0.0191a	0.0297a	0.0826	0.1048
1999	April	---	0.0065	0.0026	0.0102	---	---
	May	---	0.0040	0.0028	0.0089	---	---
	June	---	0.0161	0.0053	0.0138	0.1510	0.1178
	July	---	0.0010	0.0005	0.0080	---	---
	August	---	0.0007	0.0006	0.0003	0.0136	0.0127
	Total	---	0.0284ab	0.0119b	0.0411a	0.0329	0.0261
2000	May	---	0.0003	0.0001	0.0013	---	---
	June	---	0.0007	0.0003	0.0008	---	---
	July	---	0.0000	0.0000	0.0000	---	---
	Total	---	0.0008a	0.0004a	0.0021a	---	---
2001	March	0.0000	0.0000	0.0000	0.0000	---	---
	April	0.0000	0.0000	0.0000	0.0000	---	---
	May	0.0040	0.0003	0.0003	0.0043	---	---
	June	0.0020	0.0007	0.0007	0.0013	---	---
	July	0.0001	0.0000	0.0000	0.0000	---	---
	Total	0.0061	0.0012a	0.0010a	0.0056a	---	---
2002	May	0.0022	0.0012	0.0013	0.0018	---	---
	June	0.0028	0.0008	0.0011	0.0036	---	---
	July	0.0043	0.0004	0.0014	0.0050	---	---
	August	0.0032	0.0010	0.0013	0.0046	---	---
	Total	0.0125	0.0034a	0.0051a	0.0149a	---	---
2003	May	0.0177	0.0097	0.0043	0.0113	---	---
	June	0.0013	0.0003	0.0012	0.0014	---	---
	July	0.0028	0.0019	0.0026	0.0150	---	---
	Total	0.0218	0.0119ab	0.0081b	0.0276a	---	---
6-yr average		0.0135	0.0129a	0.0076a	0.0202a	0.0578	0.0655

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. □ – means no data.

Table 3.14. Average monthly and yearly PO_4-P loss with subsurface drainage and runoff water from lysimeters (1998-2003).

Year	Month	Subsurface Drainage Flow		
		UAN*	PM	PM2
		PO_4-P Loss (kg/ha)		
1998	May	0.0725	0.0030	0.0028
	June	0.2888	0.2922	0.0356
	July	0.0683	0.0024	0.0020
	Total	0.4296b¶	0.2976ab	0.0404a
1999	April	0.0443	0.0123	0.0245
	May	0.0249	0.0198	0.1191
	June	0.0204	0.0296	0.0342
	July	0.0057	0.0055	0.0063
	August	0.0378	0.0192	0.0230
	Total	0.1331a	0.0864a	0.2071a
2000	May	0.0037	0.0018	0.0037
	June	0.0110	0.0048	0.0097
	July	0.0000	0.0000	0.0000
	Total	0.0147a	0.0066a	0.0134a
2001	May	0.0430	0.0371	0.0612
	June	0.0036	0.0030	0.0034
	July	0.0004	0.0002	0.0004
	Total	0.0470a	0.0403a	0.0650a
2002	May	0.0040	0.0030	0.0057
	June	0.0022	0.0025	0.0021
	July	0.0038	0.0043	0.0029
	August	0.0020	0.0029	0.0000
	Total	0.0119a	0.0128a	0.0107a
2003	April	0.0032	0.0038	0.0035
	May	0.0079	0.0113	0.0127
	June	0.0027	0.0026	0.0026
	July	0.0049	0.0077	0.0046
	Total	0.0187a	0.0255a	0.0234a
6-yr average		0.1092a	0.0782a	0.0600a

* UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05.

Table 3.15. Six-year averages for drainage flow, NO_3-N and PO_4-P concentrations, and NO_3-N and PO_4-P losses (1998-2003).

Parameters	Field Plots				Lysimeters		
	Check**	UAN	PM	PM2	UAN	PM	PM2
Subsurface Drainage Flow							
Total Yearly Tile Flow (cm)	15.79	11.15b¶	8.41a	10.35ab	26.31a	24.17a	25.53a
Average NO_3-N Concentrations (mg/L)	7.79	19.49b	17.39b	27.52a	14.84ab	7.73b	15.63a
Total Yearly NO_3-N Losses (kg/ha)	13.39	22.97ab	15.43b	28.07a	42.68a	20.31a	42.10a
Average PO_4-P Concentrations (μ/L)	4.76	6.35ab	5.21b	15.36a	37.47a	28.57a	20.23a
Total Yearly PO_4-P Losses (kg/ha)	0.01349	0.0129a	0.0076a	0.0202a	0.1092a	0.0782a	0.0600a
Runoff Flow***							
Total Yearly Runoff (cm)	---♣	---	0.59	0.54	---	---	---
Average NO_3-N Concentrations (mg/L)	---	---	9.32	11.67	---	---	---
Total Yearly NO_3-N Losses (kg/ha)	---	---	0.55	0.63	---	---	---
Average PO_4-P Concentrations (μ/L)	---	---	979.7	1213.0	---	---	---
Total Yearly PO_4-P Losses (kg/ha)	---	---	0.0578	0.0655	---	---	---

* Check: 0 kg N/ha; UAN: 168 kg N/ha from UAN fertilizer; PM: 168 kg N/ha from poultry manure; PM2: 336 kg N/ha from poultry manure.

¶ Mean values for each variable in the same row followed by the same letter are not significantly different at significance level of P = 0.05. ♣ – means no data.

**Data for check plots were available only for 2001-2003, therefore they were not included in the statistical analysis.

*** Runoff data were collected from a single plot for each treatment, therefore, no statistical analysis were conducted.

The PM treatment resulted in lower NO_3-N concentrations and overall lower losses with runoff water in comparison with the PM2 treatment (Table 3.15).

NO_3-N Losses with Subsurface Drainage and Runoff Waters

Subsurface Drainage Water. The results of this study indicated that larger NO_3-N losses in field plots could be possible under the UAN treatment in comparison to that of those under the PM treatment. It must be remembered that the subsurface drainage flow volumes for the PM treatment were lower in comparison to other treatments (Table 3.15).

Flow data for the lysimeters' subsurface drainage flow indicate that there were not significant differences among treatments on subsurface drainage flow volumes. The UAN fertilizer treatment resulted in NO_3-N losses equivalent to the double rate of the poultry manure application. Therefore, the UAN fertilizer treatment resulted in higher NO_3-N losses in comparison with the PM treatment at a similar nitrogen application rate (Table 3.15).

Larger NO_3-N losses with runoff from the field plots were observed in comparison with the PM2 treatment (Table 3.15).

The Effects of Poultry Manure Applications on PO_4-P Concentrations in Subsurface Drainage and Runoff Water

Subsurface Drainage. The data in Table 3.15 show clearly that the PM2 treatment resulted in almost two fold higher PO_4-P concentrations with subsurface drainage water in comparison with the PM treatment. This indicates that doubling the application rate of poultry manure can result in almost a two fold leaching of PO_4-P concentrations in subsurface drainage water. The data from lysimeters did not show any significant difference in PO_4-P leaching with subsurface drainage water (Table 3.15).

Runoff Water. Data on PO_4-P concentrations in runoff water show no significant differences between the treatments although higher poultry manure application rates resulted in higher PO_4-P concentrations with runoff water compared to the lower poultry manure application rate (PM treatment)(Table 3.15).

PO_4-P Losses with Subsurface Drainage and Runoff Water

Subsurface Drainage. The data from field plots show that the PM treatment resulted in the lowest PO_4-P losses with subsurface drainage water. In addition the PM effects on PO_4-P losses were significantly lower than from the PM2 treatment (Table 3.15).

The data in Table 3.15 show that lysimeter PO_4-P concentrations were not statistically different between the treatments. Also, the UAN treatment resulted in about double the PO_4-P concentration in drainage water in comparison with that of the poultry manure treatments.

Runoff Losses. The PM treatment resulted in lower PO_4-P losses in comparison with the PM2 treatment (Table 3.15).

Conclusions

This study resulted in the following conclusions. The NO_3-N and PO_4-P concentrations in subsurface drain water were significantly lower under the PM treatment (168 kg N/ha from poultry manure) in comparison with the other two treatments. Also the corn yields (as discussed in Chapter 2 of this thesis) under the PM treatment were significantly higher in comparison with the other two treatments. This shows that if poultry manure is applied at a rate of 168 kg N/ha, farmers can expect to obtain better yields and lower NO_3-N and PO_4-P leaching to groundwater.

References

Beyer, Scott R. Revised 2002. *Frequently Asked Questions About Poultry.* Kansas State University Research and Extension. Publication not numbered. http://www.oznet.ksu.edu/poultry/faq.htm#E.%20Layers (Date accessed: November 19, 2003)

Blackmer, A.M. and A.P. Mallarino. Sept. 2000. *Cornstalk testing to evaluate nitrogen management.* University Extension, Iowa State University. Publication PM1584. http://www.extension.iastate.edu/Publications/PM1584.pdf (Date accessed: November 19, 2003)

Blanchet, L. 1996. Impact of lime application on transport of nitrate-nitrogen, atrazine, and cyanazine to subsurface drainage water: A lysimeter study. MS thesis. Ames, Iowa: Iowa State University.

Chinkuyu, Adion. 2000. Environmental impacts of the use of poultry manure for agricultural production systems. PhD dissertation. Ames, Iowa: Iowa State University.

Chinkuyu, Adion, R.S. Kanwar, J.C. Lorimor, H. Xin, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. *Transactions of the ASAE* 45(2): 299-308.

Hach Company, 1997. *Water Analysis Handbook.* 3rd ed. Hach Company, Loveland, CO.

Kanwar, R.S., J.L. Baker, and D.G. Baker. 1988. Tillage and split N-fertilization effects on subsurface drainage water quality and crop yields. *Trans. ASAE* 31(2): 453-461.

Killorn, Randy and Jeff Lorimor. 1999. *Managing Manure Nutrients for Crop Production.* University Extension, Iowa State University. Publication PM1811. http://www.extension.iastate.edu/Publications/PM1811.pdf (Date accessed: November 19, 2003)

Klapper, Betty, H. M. Taybor, M. G. Huck, and E. L. Fiscus. 1973. Water relations and growth of cotton in drying soil. *Agronomy Journal.* Vol. 65: 307-310.

National Atlas of the United States, December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

Schwantz, Lee. 1979. "Feeding Instructions." Farmer's Digest. Wisconsin. (Referenced from *The Family Poultry Flock*) Website: *CHICKEN FEED: The* World of Chickens http://www.lionsgrip.com/feedinstruc.html (Date accessed: November 19, 2003)

Soil Conservation Service. 1992. *National Engineering Handbook: Agricultural Waste Management Field Handbook.* United States Department of Agriculture.

Soil Survey Division (SSD), Natural Resources Conservation Service, United States Department of Agriculture. *Official Soil Series Descriptions* [Online WWW]. http://ortho.ftw.nrcs.usda.gov/osd/ (Date accessed: January 3, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 1999. *Agricultural Statistics 1999.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2000. *Agricultural Statistics 2000.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2001. *Agricultural Statistics 2001.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2002. *Agricultural Statistics 2002.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2003. *Agricultural Statistics 2003.* www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Interior. 2000. *National Atlas of the United States.* December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

U.S. Geological Survey. October 2002. "Cities and Towns", *in National Atlas of the United* States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey. November 2002. "Aquifers of Alluvial and Glacial Origin", *in National Atlas of the United States.* http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey. January 2002. "Roads", *in National Atlas of the United States.* http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey. July 2002. "States", *in National Atlas of the United States.* http://nationalatlas.gov. (Date accessed: November 19, 2003)

CHAPTER 4. THE EFFECTS OF POULTRY MANURE ON SOIL QUALITY USING FIELD PLOTS

A paper to be submitted to the Journal of American Water Resources Association (JAWRA)

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Abstract

A six-year study (1998-2003) was conducted to determine the effects of poultry manure on long-term soil quality. Eleven experimental plots were used for this study. Three experimental treatments were used to give N applications at rates of: *i*) 168 kg N/ha from poultry manure (PM), *ii*) 168 kg N/ha from urea-ammonium nitrate (UAN), and, *iii*) 336 kg N/ha from poultry manure (PM2). Each of these treatments were replicated three and four times using ten of the eleven plots. The eleventh plot was used as a check plot with zero application of nitrogen from UAN or poultry manure. These field plots were planted to a corn-soybean rotation. The results of this indicate that the PM treatment resulted in high yields, which were significantly higher in comparison with the UAN treatment. In addition, the PM treatment resulted in reduced concentrations of soil NO_3-N compared to UAN treatment and lower soil concentrations of PO_4-P when compared with the PM2 treatment. The overall results of this study indicate that the poultry manure applied at rates of 168 kg N/ha resulted in better crop yields and reduced concentrations of soil NO_3-N in comparison with the 168 kg N/ha from UAN and lower soil PO_4-P concentrations when compared to 336 kg N/ha application rate from poultry manure.

Key Terms: poultry manure, field plots, corn soybean rotation, water quality, agricultural hydrology, soil PO_4-P, soil NO_3-N

Introduction

Iowa's egg industry continues to grow each year. In 2001 Iowa became the number one egg producing state in the US, producing 8.69 billion eggs (USDA-NASS, 2002). In 2002, Iowa broke its record producing 9.91 billion eggs, thus maintaining its position as number one egg producing state for 2002 (USDA-NASS, 2003) (Table 4.1). In order for Iowa to continue producing such a high number of eggs, an average of 675 million pounds of feed every year would be required leading to the generation of some 817 million pounds of manure per year (Beyer, 2002; Schwantz, 1979; SCS, 1992; USDA-NASS, 2003) (This does not include waste from other types of poultry operations such as broilers etc.) (Table 4.2). With so much poultry manure being generated every year brings the need to find ways to manage this manure so that it does not create environmental problems. The most common way of utilizing manure is to apply it on fields to help add valuable plant nutrients for growing crops. Unfortunately, the amount of nutrients present in the manure typically is not present in the same ratios as are needed by the crops to be grown. This can result in the over application of some nutrients especially phosphorus leading to water quality problems. To help solve water quality problems, policies were developed in Iowa on how much manure could to be applied to fields based on the nitrogen requirements of the crops. Over time the excess phosphorus builds up in the soil and is washed off from fields into runoff and subsurface tile flow. This can lead to other water quality problems. Thus, other methods of nutrient management are needed in order to reduce the high phosphorus levels that have become prevalent in soils that were being overly applied with manure and to prevent phosphorus losses from fields to Iowa's water bodies.

Table 4.1. Iowa's egg industry statistics for the years 1998-2002.

Year	Rank	No. of eggs produced	Average No. of Layers	Rate of Egg Laying Per Year Per Hen
1998	4th	5,969,000,000	23,044,000	259
1999	2nd	6,754,000,000	25,623,000	264
2000	2nd	7,554,000,000	28,098,000	269
2001	1st	8,691,000,000	32,591,000	267
2002	1st	9,910,000,000	36,980,000	268

*Information from the USDA National Agricultural Statistics Service (USDA-NASS, 2003, 2002, 2001, 2000, 1999)

Table 4.2. Calculations for feed use and waste production by laying hens.

Assumptions:

1 Iowa has an average of 36,980,000 layer hens in 2002 (NASS, 2002)
Each layer hen produce 268 eggs per year
Iowa produced 9,910,000,000 eggs in 2002

2 Layer hen cycle = 12 months (Beyer, 2002)

3 0.5 lb of 15% protein feed given per 10 hens per day (Schwantz, 1979)

4 60.5 lb manure/1000 layer hens is produced each day having a volume of 0.93 ft^3 manure/1000 hens/day (value is manure as excreted with moisture being 75% of total wt) (SCS, 1992)

Amount of feed needed to supply Iowa layer hens in a year 2002.

$$36{,}980{,}000 \text{ hens} \ast \frac{0.5 \text{ lb feed}}{10 \text{ hens} \ast \text{day}} \ast \frac{365 \text{ days}}{1 \text{ year}} = \mathbf{\frac{674{,}885{,}000 \text{ lb feed}}{\text{year}}}$$

Amount of manure generated by Iowa layer hens in 2002.

$$36{,}980{,}000 \text{ hens} \ast \frac{60.5 \text{ lb manure}}{\text{day} \ast 1000 \text{ hens}} \ast \frac{365 \text{ days}}{1 \text{ year}} = \frac{816{,}610{,}850 \text{ lb manure}}{\text{year}} = \mathbf{\frac{816{,}611{,}000 \text{ lb manure}}{\text{year}}}$$

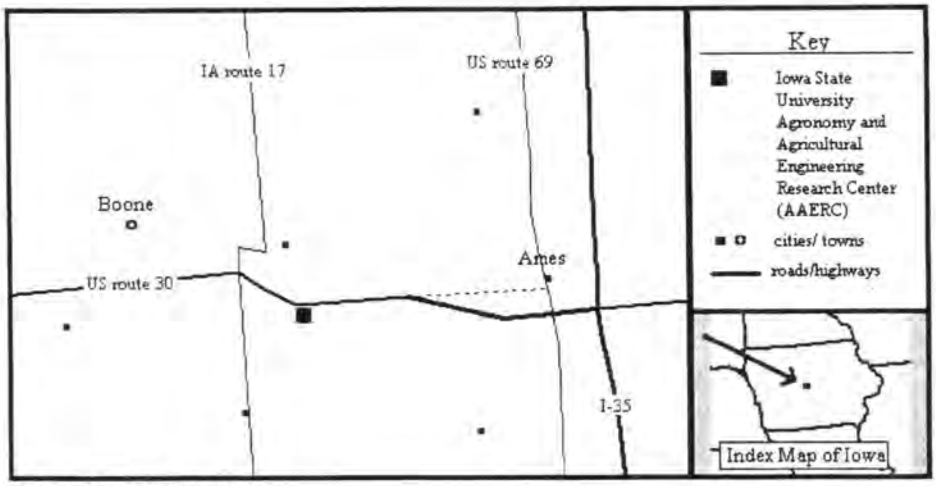
$$36{,}980{,}000 \text{ hens} \ast \frac{0.93 \text{ ft}^3 \text{ manure}}{\text{day} \ast 1000 \text{ hens}} \ast \frac{365 \text{ days}}{1 \text{ year}} = \frac{12{,}552.861 \text{ ft}^3 \text{ manure}}{\text{year}} = \mathbf{\frac{12{,}553{,}000 \text{ ft}^3 \text{ manure}}{\text{year}}}$$

A six-year study was conducted (from 1998 through 2003) in order to better understand how poultry manure applied to field plots impacts crop growth and soil nutrients. Specifically, the questions being addressed were *i*) what was optimum application of poultry manure to obtain high corn and soybean yields without degradation of soil and water quality, *ii*) how do N treatments affect soil NO_3-N and PO_4-P in comparison with the soil nutrient scales recommended by Mallarino et al. (2003), Mallarino et al. (2000), Sawyer et al. (2003), and Blackmer et al. (1997) for relative soil nutrient levels, *iii*) which of the N treatments resulted in higher and lower soil NO_3-N and PO_4-P levels in each growing season and, and *iv*) did any treatment result in a gradual build up or decline in NO_3-N or PO_4-P concentrations in the soil over time? At present, soil sampling for the last year of the study is still in progress and will be completed by the end of year (2003).

Materials and Methods

Site Location and Experimental Units

This study was conducted in Field 5 at the Iowa State University Agronomy and Agricultural Engineering Research Center located on US highway 30 between Ames and Boone, Iowa (Figure 4.1). The soils in Field 5 are a part of the Clarion-Nicollet-Webster soil association (Blanchet, 1996; Chinkuyu et al., 2002; Chinkuyu, 2000). These soils were derived from glacial till laid down during the last glacial retreat that extended throughout an area of Iowa known as the Des Moines lobe advance (SSD, no date; Chinkuyu et al., 2002; Chinkuyu, 2000) [Figure 4.2]. Originally, these soils yielded prairie vegetation before being converted to productive farmland (Chinkuyu et al., 2002; Chinkuyu, 2000) [More information about Field 5 soils can be obtained in Appendix A.].



National Atlas of the United States

Figure 4.1. Location of Agronomy and Ag. Engineering Research Farm in relation to Ames, and Boone.

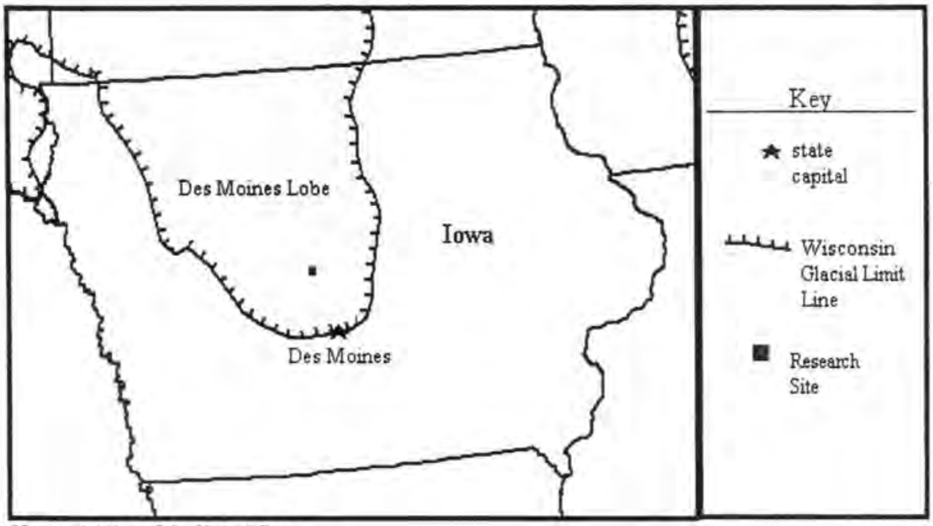


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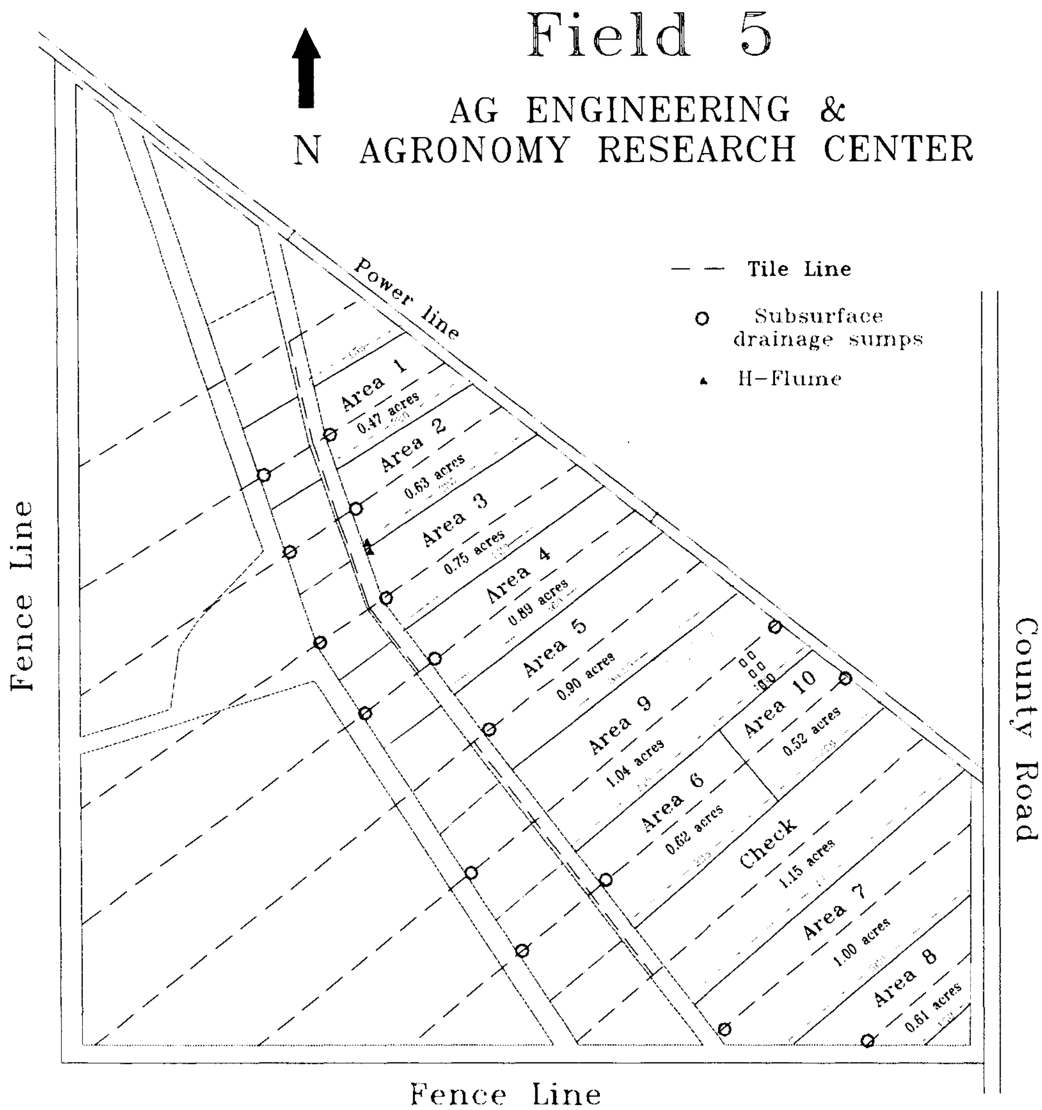
Figure 4.2. Extent Des Moines Lobe Glacial Advance.

Within field 5 are the eleven field plots that were used in this experiment. The field plots, as shown in Figure 4.3, vary in size from 0.19 ha (0.47 ac) to 0.42 ha (1.04 ac). These field plots were established in 1984 and plot is drained by a single subsurface tile drain through the center of the plot and is intercepted by a sump containing monitoring devices for measuring water flow and collecting samples for water quality analysis (Kanwar et al., 1988; Blanchet, 1996). The sump for the control (check) plot was not installed until fall 1999.

Experimental Treatments: Manure/Fertilizer Applications

Laying hen poultry manure used in this experiment was obtained from a laying hen farm located in Humboldt, Iowa. Prior to applying the poultry manure to the field plots and lysimeters, samples of the manure were taken and sent to MVTL Laboratories, Inc., located in Nevada, Iowa, to test for total moisture, total nitrogen, phosphorus, potassium, and ammonia-nitrogen. Results from the analysis are given in Table 4.3.

The following treatments were applied on the field plots: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), *iii*) 336 kg N/ha from poultry manure (PM2), and *iv*) 0 kg N/ha (control treatment). These treatments were randomly assigned to each field plot, but due to the number of field plots available, the treatments were unbalanced with the UAN treatment having four replicates, PM treatment having three replicates, the PM2 treatment having three treatments, and the control treatment having one replicate. Figure 4.3 shows which field plots received what treatment.



1	336 kg-N/ha	Poultry Manure		6	168 kg-N/ha	UAN Fertilizer
2	168kg-N/ha	Poultry Manure		7	336 kg-N/ha	Poultry Manure
3	336 kg-N/ha	Poultry Manure		8	168 kg-N/ha	UAN Fertilizer
4	168 kg-N/ha	UAN Fertilizer		9	168 kg-N/ha	UAN Fertilizer
5	168 kg-N/ha	Poultry Manure		10	168 kg-N/ha	Poultry Manure

Check Plot : No Poultry Manure or UAN Fertilizer

Figure 4.3. Field Plots in Field 5.

Table 4.3. Characteristics of poultry manure applied to field plots.

Characteristics	1998	1999	2000	2001	2002	2003
			168 kg N/ha Poultry Manure Treatment			
Total Kjedhal N (TKN), % N	1.49	3.04	2.69	2.16	1.41	2.03
Ammonia (NH_3), %N	1.00	4.37	3.94	2.72	2.24	1.60
Total Phosphorus, %P	1.43	2.29	2.41	20.62	1.20	1.81
Potassium, %K	1.11	0.74	0.72	8.50	0.57	1.71
Moisture Content, %H_2O	48.12	45.03	32.60	56.97	53.70	76.25
			336 kg N/ha Poultry Manure Treatment			
Total Kjedhal N (TKN), % N	1.51	2.98	3.73	2.16	1.41	2.03
Ammonia (NH_3), %N	0.94	4.21	3.76	2.72	2.24	1.60
Total Phosphorus, %P	1.25	1.86	2.25	20.62	1.20	1.81
Potassium, %K	1.06	0.82	0.78	8.50	0.57	1.71
Moisture Content, %H_2O	46.88	54.60	32.23	56.97	53.70	76.25

*Conversion for nutrients: % *20 = lbs/ton

Table 4.4. Average manure application rates for field plots (1998-2003).

	168 kg N/ha poultry manure				336 kg N/ha poultry manure			
	Average manure application rate, kg/ha	Average application rate, kg/ha*			Average manure application rate, kg/ha	Average application rate, kg/ha*		
		N	P	K		N	P	K
1998	10674	159	107	152	24190	364	227	303
1999	9575	291	418	220	14774	440	622	275
2000	3213	86	126	78	8741	326	329	196
2001	8998	195	244	1855	14957	324	406	3083
2002	7982	113	179	96	14295	202	320	172
2003	11318	229	181	205	18231	369	292	330
6-yr average	8627	179	209	434	15865	337	366	727

* Assumed 5% N, P, and K lost during application; 75% N, P, and K available during the first year. In subsequent years no credit was given for residual N, P, and K from the manure or N from soybeans.
¶ Intended N application rates from layer manure were 168 kg-N/ha and 336 kg-N/ha, however, actual N application rates averaged PM = 179 kg-N/ha and PM2 = 337 kg-N/ha for the plots; PM = 218 kg-N/ha and PM2 = 436 kg-N/ha for the lysimeters.

The manure was applied to the field plots by surface broadcast on one half of the plots, which are planted in corn. The other half of each field plot that was planted to soybeans received no manure or N fertilizer. After manure or UAN fertilizer was applied to the field plots, it was incorporated into the soil that day or the day after by tilling/disking the soil down to a depth of about 15 cm (6 inches). This was done to help minimize N losses through volatilization (Chinkuyu et al., 2002; Chinkuyu, 2000). Even though the intended application rates applied to both field plots were based on the nitrogen treatments UAN, PM, and PM2, "the actual amounts of N applied to the plots were different from the desired N application rates because the N content in the manure (determined at the beginning) used in the calibration of the manure spreader was different from the N content determined at the time of application" (Chinkuyu et al., 2002; Chinkuyu, 2000). The actual N application rates for two treatments averaged *i*) PM = 170 kg N/ha and *ii*) PM2 = 321 kg N/ha for the field plots as shown in Table 4.4.

Planting

The field plots were planted to a corn-soybean rotation in such a way that both corn and soybeans are planted on the same field plot in the same year. Using the center tile drain in the middle of each field as a dividing line, one half of the field plot was planted to corn and the other half was planted to soybeans. In even years, like 1998, corn was planted on the northern half of the fields and soybeans on the southern half. Then in the following year (an odd year, like 1999), corn was planted on the southern half of the fields and the soybeans on the northern half. The corn variety Dekalb 580 and soybean variety Kruger 2426 were used in the experiment with each being planted at a spacing of 0.75 m between rows and 0.2 m between plants within each row (Chinkuyu et al., 2002; Chinkuyu, 2000). Methods used in the harvesting and grain quality analysis for field plots are given in Chapter 2 of this thesis.

Tillage

Once the field plots had been harvested, the side of each field plot that had corn for that year was tilled using a chisel plow which allows about 30% of the crop residue to remain on the surface of the soil. The side of each field plot that was planted in soybeans did not receive the fall tillage.

Soil Sampling for the Determination of NO_3-N and PO_4-P Concentrations

Soil core samples were taken each spring before planting and each fall after harvest from the field plots. Testing of the samples was done to determine what was happening in the soil between planting and after harvest with respect to NO_3-N and PO_4-P utilization by the crops. In the field plots, only the side, which was planted to corn for that year, was sampled for soil NO_3-N and PO_4-P levels. [It was assumed that the side of the field plots planted to soybeans for that year would have a reduced levels of soil PO_4-P because no manure/fertilizer was added to the soybeans portion of the plot. Soil NO_3-N may or may not change in the soybean portion of the plot depending on the amount of nitrogen that is produced by the soybeans.] The scales used to analyze the amount of PO_4-P and NO_3-N present in a soil sample are given in Table 4.5 and 4.6.

Soil samples were taken from the field plots with the help of a hydraulically operated auger machine. A four-foot long plastic tube was slipped into the machines metal auger to act as a lining during the soil coring that became becomes the soil container afterwards. After the machine takes a soil core sample, the plastic tube was removed (containing the soil). Caps were placed on both ends of the tube, and then the soil tube was labeled. The holes created in

Table 4.5. Soil Phosphorus Determination by Bray P_1 (ppm)

Relative Level	At Low pH (< 7)	At High pH (> 7)
Very Low (VL)	0-8	0-5
Low (L)	9-15	6-10
Optimum (Opt)	16-20	11-15
High (H)	21-30	16-20
Very High (VH)	31+	21+

(Mallarino et al., 2003; Mallarino et al., 2000; Sawyer et al., 2003)

Table 4.6. Soil Nitrate Determination

Soil NO_3-N (ppm)	Soil N Credit (kg N/ha)	Estimated N to Apply (kg N/ha)
0-10	75	101
11-15	113	67
16-25	151	34
25+	188	0

(Blackmer et al., 1997)

the field plots after collecting soil samples were filled with granular bentonite. Three soil core samples were collected from each field plot (going across the field every so many rows each time). The soil cores were then stored in a freezer until the samples analyzed for NO_3-N and PO_4-P concentrations in the lab.

Soil Preparation

After the frozen soil cores were taken out of the freezer, they were allowed to thaw. The soil cores were then cut into five pieces based on soil depth from the surface down as follows: 0-6 in (0-15 cm), 6-12 in (15-30 cm), 12-24 in (30-61 cm), 24-36 in (61-91 cm), and 36-48 in (91-121cm). Since each field plot had three soil cores, the three soil samples from the same plot and same depth were mixed together to give a composite sample for each plot and for one depth. The soil sample for each depth was then bagged and labeled making a total of five samples per each experimental plot. The bagged soil samples were then analyzed in the lab for NO_3-N and PO_4-P concentrations.

Results and Discussion

Statistical Analysis

The data obtained from this study were tested using a split-plot model design using SAS version 8.2. First the data were tested using an F test. If the results indicated that there were significant differences in the treatment results, then a student t-test was performed to indicate the significance between treatments. Tests on soil NO_3-N and PO_4-P concentrations were conducted using an alpha of 0.10. For statistical analysis of soil nutrient concentrations, the control treatment was not included in the statistical analysis because we had only one replication for the control treatment; only the numeric value was still included in the result tables for comparison purposes.

Effects of Poultry Manure on Soil Quality

Since we were interested in the of soil NO_3-N and PO_4-P concentrations in the top 15 cm of the soil, the soil cores obtained from 0-15 cm depth are discussed in the following sections.

Soil NO_3-N

The soil NO_3-N concentrations for field plots (Table 4.7), based on the soil NO_3-N nutrient scale given by Blackmer et al., 1997, show that the PM2 and UAN treatments applied over a five year period resulted in buildup of soil nitrogen to levels to where less nitrogen application was needed for growing crops in comparison with those field plots under the PM and control treatments. This shows that when poultry manure is applied to give 168 kg N/ha, there is less likelihood of building up the residual soil-N levels.

Field plot soil NO_3-N levels, given in Table 4.7, show that average soil NO_3-N concentrations in the PM2 treatment plots were significantly higher in comparison with the soil NO_3-N in PM treatment plots. No significant differences in soil NO_3-N concentrations were observed between UAN and PM2 treatments. Spring soil NO_3-N concentrations are given in Table 4.7. The results in Table 4.7 show that UAN treatment effects on soil NO_3-N resulted in significantly higher than soil NO_3-N when compared with the PM treatment. In addition, the PM2 treatment resulted in higher soil on soil NO_3-N concentrations in comparison with the PM treatment. For fall soil NO_3-N data, the PM treatment resulted in

Table 4.7 Field plot average soil NO_3-N and PO_4-P at depth 0-15 cm (1998-2002).

Year	Soil NO_3-N (ppm)				Soil PO_4-P (Bray-P)			
	Check#	UAN	PM	PM2	Check	UAN	PM	PM2
Spring 1998	12.00	22.93	11.10	14.87	13.50	28.15	31.87	24.27
Fall 1998	7.90	10.00	11.40	16.93	38.00	33.75	64.17	85.33
Spring 1999	16.00	35.78	10.77	12.73	18.00	37.50	42.50	32.33
Fall 1999	2.30	7.95	7.67	13.30	18.50	32.95	54.77	57.67
Spring 2000	16.80	19.15	17.53	22.28	25.50	39.25	68.00	90.67
Fall 2000	11.60	8.13	14.13	12.42	50.00	58.00	82.00	70.57
Spring 2001	16.75	18.21	21.83	23.80	19.50	30.88	68.10	51.57
Fall 2001	2.50	17.70	16.28	23.28	10.00	22.13	40.33	63.83
Spring 2002	13.50	15.73	14.28	14.57	17.50	33.75	54.50	87.00
Fall 2002	4.84	7.28	6.47	10.00	25.00	23.63	60.83	125.00
Average	10.42**	16.29ab*	13.15b	16.42a	23.55	34.00b	56.71a	68.82a
Spring 1998	12.00	22.93	11.10	14.87	13.50	28.15	31.87	24.27
Spring 1999	16.00	35.78	10.77	12.73	18.00	37.50	42.50	32.33
Spring 2000	16.80	19.15	17.53	22.28	25.50	39.25	68.00	90.67
Spring 2001	16.75	18.21	21.83	23.80	19.50	30.88	68.10	51.57
Spring 2002	13.50	15.73	14.28	14.57	17.50	33.75	54.50	87.00
Average	15.01	22.36b	15.10a	17.65ab	18.80	33.91b	52.99a	57.17a
Fall 1998	7.90	10.00	11.40	16.93	38.00	33.75	64.17	85.33
Fall 1999	2.30	7.95	7.67	13.30	18.50	32.95	54.77	57.67
Fall 2000	11.60	8.13	14.13	12.42	50.00	58.00	82.00	70.57
Fall 2001	2.50	17.70	16.28	23.28	10.00	22.13	40.33	63.83
Fall 2002	4.84	7.28	6.47	10.00	25.00	23.63	60.83	125.00
Average	5.83	10.21b	11.19b	15.19a	28.30	34.09b	60.42b	80.48a

Check: 0 kg-N/ha; UAN: 168 kg-N/ha from UAN fertilizer; PM: 168 kg-N/ha from poultry manure; PM2: 336 kg-N/ha from poultry manure.

* Values in the same row followed by the same letter are not significantly different at significance level of P = 0.10. ♣ --- means no data.

**Only one replicate for check plot data, therefore is not included in the statistical analysis and is included in table for numeric comparison only.

significantly higher soil NO_3-N concentrations in comparison with the UAN and PM treatment effects.

Soil NO_3-N concentrations trends over five years show that soil NO_3-N concentrations from UAN and control treatment plots experienced declines in comparison with the PM and PM2 treatments (Figure 4.4). When looking at the spring soil NO_3-N trends, the soil NO_3-N concentrations from the UAN treatment showed a decline in comparison with the soil NO_3-N from PM, PM2, and control treatment (Figure 4.5). In addition, the overall average fall soil NO_3-N concentrations showed an increase in soil NO_3-N concentrations in the UAN treatment plots in comparison with the soil NO_3-N concentration in other treatment plots (Figure 4.6).

Soil PO_4-P

Based on the low pH scale for relative soil PO_4-P levels (Mallarino et al., 2003; Mallarino et al., 2000; Sawyer et al., 2003), the average soil PO_4-P concentrations in all treatment plots indicated high to very high levels of available soil PO_4-P. This was possible only due to very high levels of PO_4-P build up in plots from phosphorus fertilizer applications that had been applied to these field plots over many years prior to this study. Average soil PO_4-P concentrations for field plots given in Table 4.7 showed that soil PO_4-P concentrations in the UAN treatment plots were significantly lower in comparison with the PM and PM2 treatment plots. Also, soil PO_4-P concentrations in the PM2 treatment plots were higher when compared to the PM treatment plots. Similar results were observed for the spring soil PO_4-P concentrations data (Table 4.7). For fall soil PO_4-P concentrations it can be clearly seen that soil PO_4-P concentrations in the UAN treatment plots were significantly lower in comparison with the PM and PM2 treatment plots. In addition, fall soil

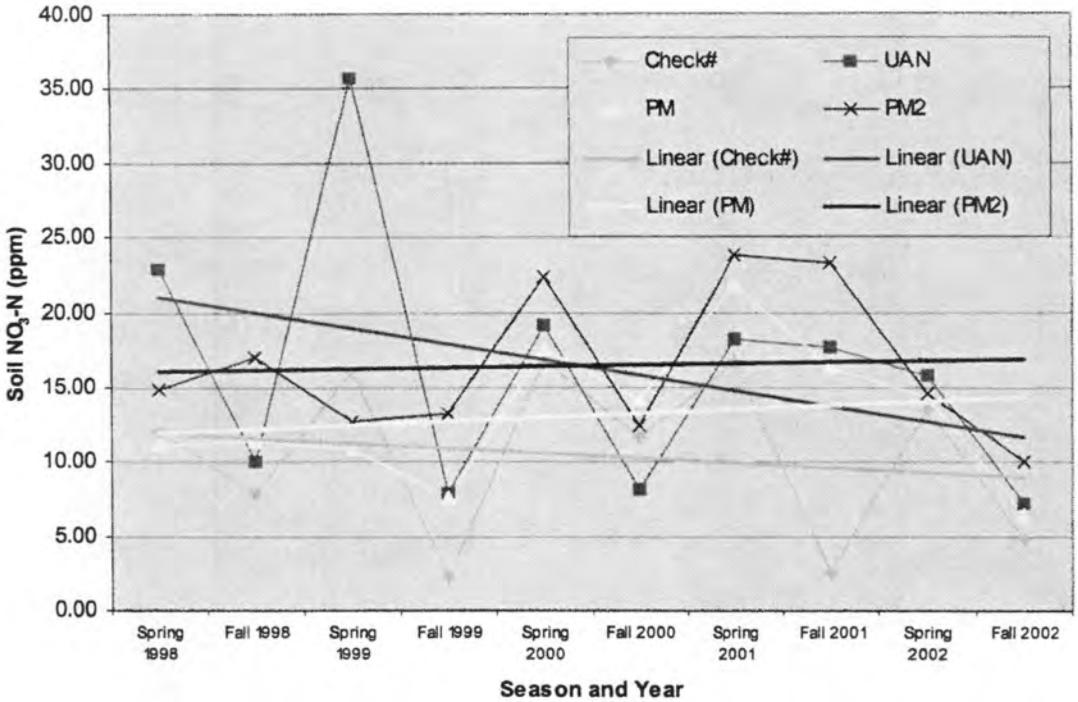


Figure 4.4. Field Plot Average Soil NO_3-N at Depth 0-15 cm (1998-2002).

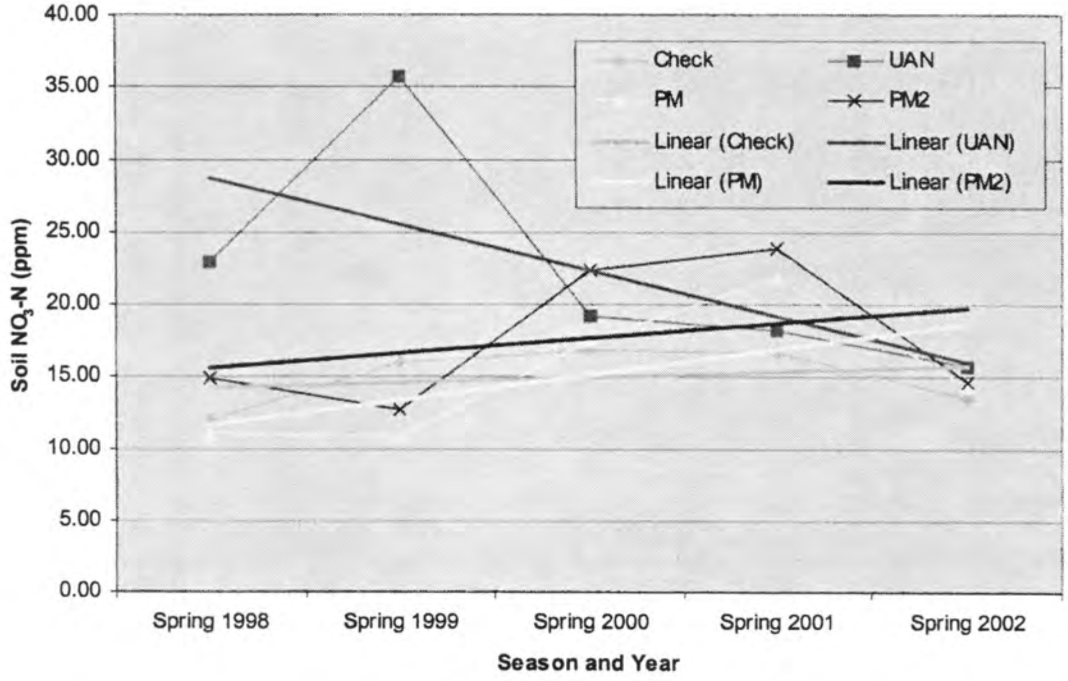


Figure 4.5 Field Plot Average Soil NO_3-N during the Spring at Depth 0-15 cm (1998-2002).

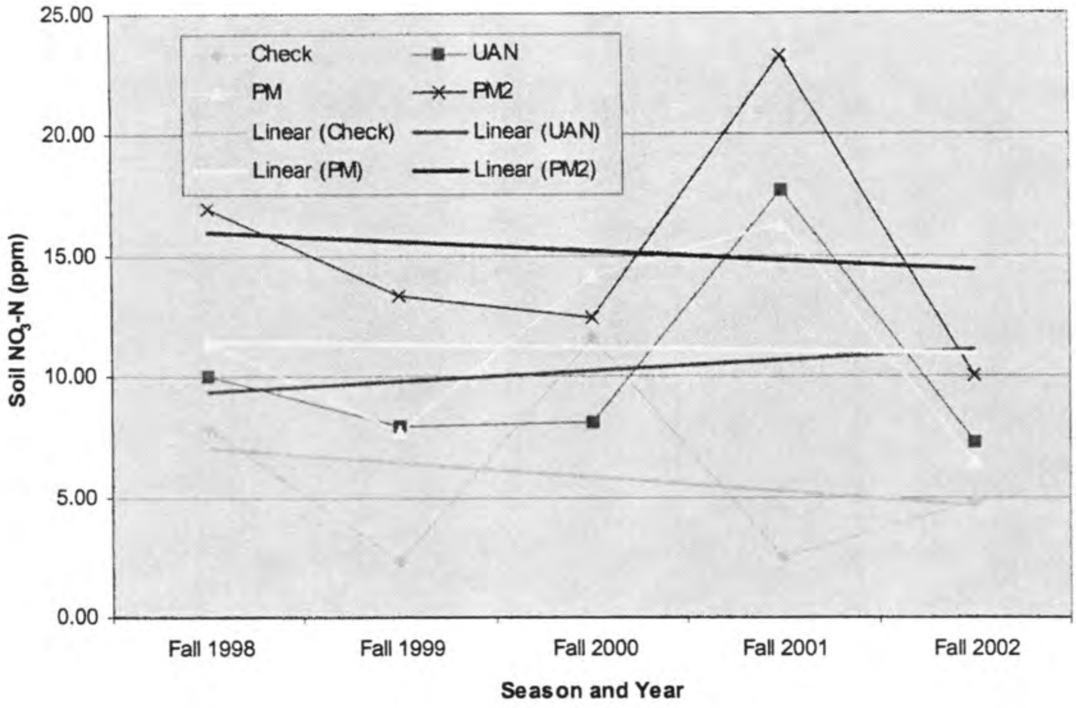


Figure 4.6 Field Plot Average Soil NO_3-N during the Fall at Depth 0-15 cm (1998-2002).

PO_4-P concentrations from PM2 treatment plots were higher in comparison with the PM treatment plots (Table 4.7).

Soil PO_4-P concentrations from the UAN and control treatment plots showed a declining trends whereas the PM and PM2 treatments showed an increasing trend in buildup soil PO_4-P concentrations (Figure 4.7). Fall average soil PO_4-P concentrations in the PM2 treatment plots showed a clear increase in soil PO_4-P concentrations when compared with all other treatment plots (Figure 4.9).

Summary and Conclusions

This study resulted in the following conclusions:

i) Soil NO_3-N concentrations in plots under the UAN and PM2 treatments were lower in comparison to the PM treatment. This was primarily because of the high residual soil NO3-N observed in one year, 1999, for the UAN plots.

ii) The data on soil PO_4-P concentrations indicated that all poultry manure treatments resulted in higher PO_4-P concentrations in the soil in comparison with the UAN and control treatments (which did not receive any P fertilizer applications during the five year study period).

iii) The overall results of this study indicate that the PM treatment is the better choice in applying poultry manure to fields because it results in the lower build up of the NO_3-N and PO_4-P concentrations in the soil. As long as the poultry manure is applied at reasonable nitrogen rates (of 168 kg N/ha), it possibly will improve soil quality, give better crop yields and allow reduced levels of soil NO_3-N and PO_4-P concentrations in comparison with the other N treatments.

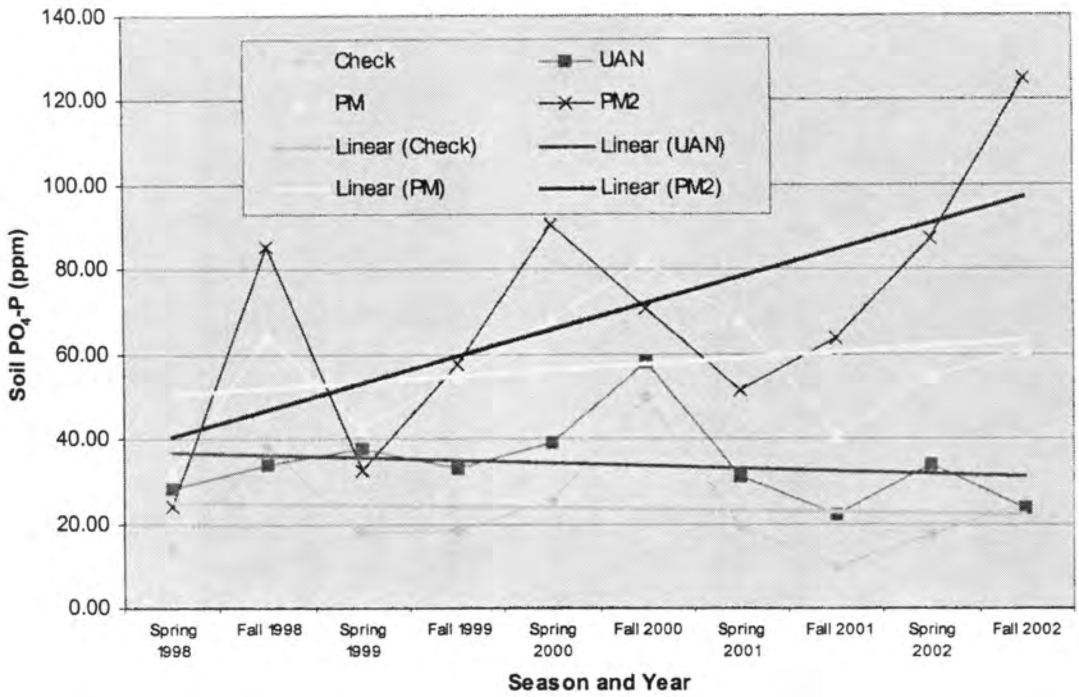


Figure 4.7. Field Plot Average Soil PO_4-P at Depth 0-6 Inches (1998-2002).

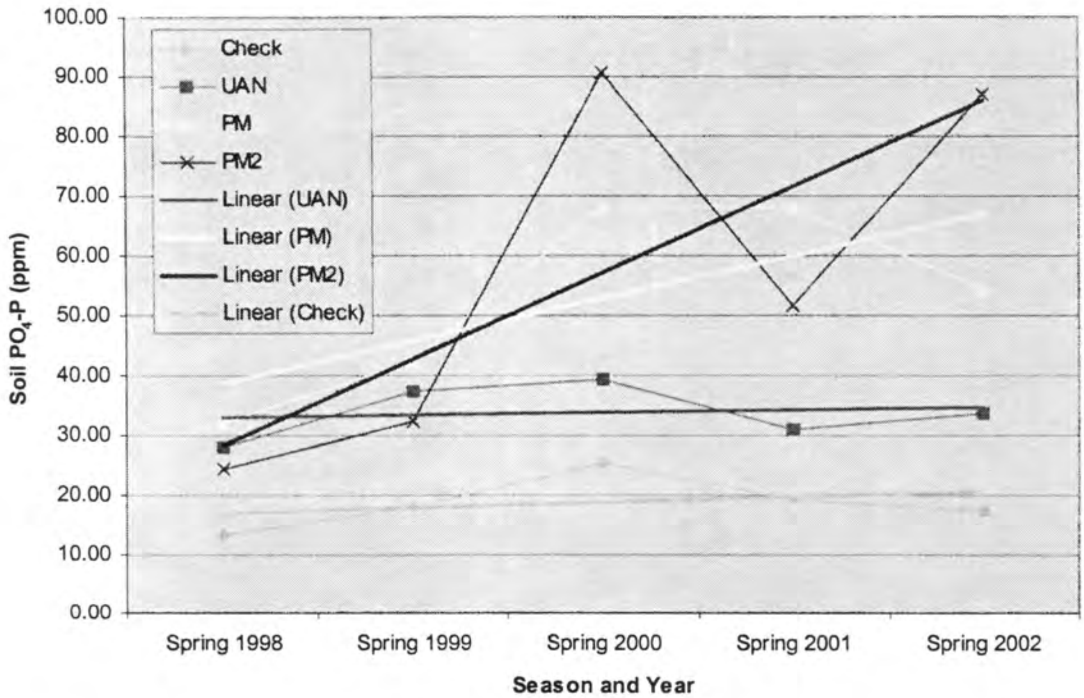


Figure 4.8. Field Plot Average Soil PO4-P during the Spring at Depth 0-6 Inches (1998-2002).

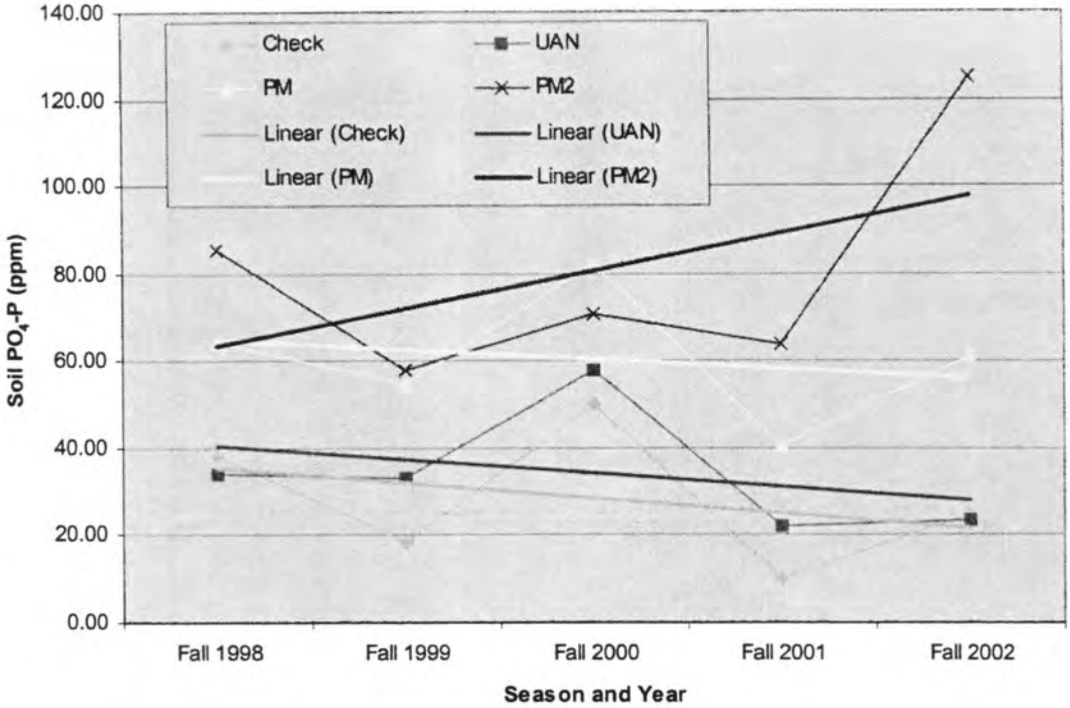


Figure 4.9. Field Plot Average Soil PO_4-P during the Fall at Depth 0-6 Inches (1998-2002).

References

Beyer, Scott R. Revised 2002. *Frequently Asked Questions About Poultry.* Kansas State University Research and Extension. Publication not numbered. http://www.oznet.ksu.edu/poultry/faq.htm#E.%20Layers (Date accessed: November 19, 2003)

Blackmer, A.M. R.D. Voss, and A.P. Mallarino. 1997. *Nitrogen Fertilizer Recommendations for Corn in Iowa.* University Extension, Iowa State University. Publication ID#: PM-1714. May 1997. (Date accessed: November 21, 2003) http://www.extension.iastate.edu/Publications/PM1714.pdf

Blackmer, A.M. and A.P. Mallarino. Sept. 2000. "Cornstalk testing to evaluate nitrogen management." Department of Agronomy, Iowa State University. http://www.extension.iastate.edu/Publications/PM1584.pdf (Date accessed: November 19, 2003)

Blanchet, L. 1996. Impact of lime application on transport of nitrate-nitrogen, atrazine, and cyanazine to subsurface drainage water: A lysimeter study. MS thesis. Ames, Iowa: Iowa State University.

Chinkuyu, Adion. 2000. Environmental impacts of the use of poultry manure for agricultural production systems. PhD dissertation. Ames, Iowa: Iowa State University.

Chinkuyu, Adion, R.S. Kanwar, J.C. Lorimor, H. Xin, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. Transactions of the ASAE 45(2): 299-308.

Kanwar, R.S., J.L. Baker, and D.G. Baker. 1988. Tillage and split N-fertilization effects on subsurface drainage water quality and crop yields. Trans. ASAE 31(2): 453-461.

Mallarino, Antonio and John E. Sawyer. 2000. *Interpreting Mehlich-3 Soil Test Results.* University Extension, Iowa State University and Department of Entomology, Iowa State University. Publication ID#: SP 126. February 2000. http://www.extension.iastate.edu/Publications/SP126.pdf (Date accessed: November 21, 2003) http://www.ipm.iastate.edu/pm/icm/1999/2-25-1999/mehlich3.html (Date accessed: November 21, 2003)

Mallarino, Antonio, John Sawyer, and John Creswell. 2003. *Nutrient Management: Soil Testing.* University Extension, Iowa State University. Publication ID#: NMEP 1. Revised September 2003. http://www.extension.iastate.edu/Publications/NMEP1.pdf (Date Accessed: November 21, 2003)

National Atlas of the United States, December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

Sawyer, J.E., A.P. Mallarino, and R. Killorn. 2003. Interpretation of Soil Test Results. University Extension, Iowa State University. Publication ID: PM 1310. March 2003. http://www.extension.iastate.edu/Publications/PM1310.pdf (Date accessed: November 21, 2003)

Schwantz, Lee. 1979. "Feeding Instructions." Farmer's Digest. Wisconsin. (Referenced from *The Family Poultry Flock*) Website: *CHICKEN FEED: The* World of Chickens http://www.lionsgrip.com/feedinstruc.html (Date accessed: November 19, 2003)

Soil Conservation Service. 1992. National Engineering Handbook: Agricultural Waste Management Field Handbook. United States Department of Agriculture.

Soil Survey Division (SSD), Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. http://ortho.ftw.nrcs.usda.gov/osd/ (Date accessed: January 3, 2003).

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 1999. Agricultural Statistics 1999. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2000. Agricultural Statistics 2000. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2001. Agricultural Statistics 2001. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2002. Agricultural Statistics 2002. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2003. Agricultural Statistics 2003. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Geological Survey, October 2002, Cities and Towns, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, November 2002, Aquifers of Alluvial and Glacial Origin, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, January 2002, Roads, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, July 2002, States, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

CHAPTER 5. EFFECTS OF POULTRY MANURE ON BACTERIA CONCENTRATIONS IN THE SUBSURFACE DRAINAGE AND RUNOFF WATER

A paper to be submitted to the Journal of American Water Resources Association (JAWRA)

Melissa Cheatham, Ramesh Kanwar, James Baker, Dan Nettleton

Abstract

The six-year study was conducted to determine the effects of four experimental treatments [168 kg-N/ha from poultry manure (PM), 168 kg-N/ha from urea-ammonium nitrate (UAN), 336 kg-N/ha from poultry manure (PM2), and 0 kg-N/ha (control treatment)] on bacteria concentrations in subsurface drainage and surface runoff water. Eleven field plots were planted to a corn-soybean rotation while six lysimeters were planted to continuous corn. The results of this study indicate that the PM treatment is the better choice for applying nutrients from poultry manure to fields because poultry manure applications at 168 kg-N/ha resulted in higher corn yields that were significantly higher in comparison with the UAN treatment at similar N application rates. Also, the PM treatment produced lower bacteria concentrations in subsurface drainage water and surface runoff water in comparison with the PM2 treatment. This shows that as long as the poultry manure is applied at nitrogen application rates (of 168 kg-N/ha), it results in better crop yields and lover bacteria concentrations in subsurface drainage and surface runoff water in comparison with the UAN and PM2 treatments, and is a good management practice in agricultural watersheds.

Key Terms: poultry manure, field plots, lysimeters, corn soybean rotation, continuous corn, water quality, agricultural hydrology, fecal and total coliform, fecal streptococcus, *Escherichia coli*

Introduction

Iowa's egg industry continues to grow each year. In 2001 Iowa became the number one egg producing state in the US, producing 8.69 billion eggs (USDA-NASS, 2002). In 2002, Iowa broke its record producing 9.91 billion eggs, thus maintaining its position as number one egg producing state for 2002 (USDA-NASS, 2003) (Table 5.1). In order for Iowa to continue producing such a high number of eggs, an average of 675 million pounds of feed per year would be required leading to the generation of some 817 million pounds of manure every year (Beyer, 2002; Schwantz, 1979; SCS, 1992; USDA-NASS, 2003) (This does not include waste from other types of poultry operations such as broilers etc.) (Table 5.2). With so much poultry manure being generated every year brings the need to find ways to manage this manure so that it does not create environmental problems. The most common way of utilizing manure is to apply it on fields to help add valuable plant nutrients for growing crops. Unfortunately, the amount of nutrients present in the manure typically is not present in the same ratios as are needed by the crops to be grown. This can result in the over application of some nutrients especially phosphorus leading to water quality problems. To help solve water quality problems, policies were developed in Iowa on how much manure could to be applied to fields based on the nitrogen requirements of the crops. Over time the excess phosphorus builds up in the soil and is washed off from fields into runoff and subsurface tile flow. This can lead to other water quality problems. Thus, other methods of nutrient management are needed in order to reduce the high phosphorus levels that have become prevalent in soils that were being overly applied with manure and to prevent phosphorus losses from fields to Iowa's water bodies.

Table 5.1. Iowa's egg industry statistics for the years 1998-2002.

Year	Rank	No. of eggs produced	Average No. of Layers	Rate of Egg Laying Per Year Per Hen
1998	4th	5,969,000,000	23,044,000	259
1999	2nd	6,754,000,000	25,623,000	264
2000	2nd	7,554,000,000	28,098,000	269
2001	1st	8,691,000,000	32,591,000	267
2002	1st	9,910,000,000	36,980,000	268

*Information from the USDA National Agricultural Statistics Service (USDA-NASS, 2003, 2002, 2001, 2000, 1999)

Table 5.2. Calculations for feed use and waste production by laying hens.

Assumptions:

1. Iowa has an average of 36,980,000 layer hens in 2002 (NASS, 2002)
   Each layer hen produce 268 eggs per year
   Iowa produced 9,910,000,000 eggs in 2002

2. Layer hen cycle = 12 months (Beyer, 2002)

3. 0.5 lb of 15% protein feed given per 10 hens per day (Schwantz, 1979)

4. 60.5 lb manure/1000 layer hens is produced each day having a volume of 0.93 ft^3 manure/1000 hens/day (value is manure as excreted with moisture being 75% of total wt) (SCS, 1992)

Amount of feed needed to supply Iowa layer hens in a year 2002.

$$36{,}980{,}000 \text{ hens} * \frac{0.5 \text{ lb feed}}{10 \text{ hens} * \text{day}} * \frac{365 \text{ days}}{1 \text{ year}} = \mathbf{\frac{674{,}885{,}000 \text{ lb feed}}{year}}$$

Amount of manure generated by Iowa layer hens in 2002.

$$36{,}980{,}000 \text{ hens} * \frac{60.5 \text{ lb manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{816{,}610{,}850 \text{ lb manure}}{\text{year}} = \mathbf{\frac{816{,}611{,}000 \text{ lb manure}}{year}}$$

$$36{,}980{,}000 \text{ hens} * \frac{0.93 \text{ ft}^3 \text{ manure}}{\text{day} * 1000 \text{ hens}} * \frac{365 \text{ days}}{1 \text{ year}} = \frac{12{,}552.861 \text{ ft}^3 \text{ manure}}{\text{year}} = \mathbf{\frac{12{,}553{,}000 \text{ ft}^3 \text{ manure}}{year}}$$

A six-year study was conducted (from 1998 through 2003) in order to better understand how poultry manure applied to field plots impacts crop growth and water quality. Specifically, the questions being addressed in this bacterial study were: *i*) what was the optimum application of poultry manure to obtain high corn and soybean yields and *ii*) what are the effects of poultry manure on bacteria concentrations in surface runoff and subsurface drainage water. To achieve these objectives, three experimental treatments were used in this study, to apply poultry manure at rates to give 168 kg-N/ha and 336 kg-N/ha, and to apply UAN fertilizer rates of 168 kg-N/ha.

Materials and Methods

Site Location and Experimental Units

This study was conducted in Field 5 at the Iowa State University Agronomy and Agricultural Engineering Research Center located on US highway 30 between Ames and Boone, Iowa (Figure 5.1). The soils in Field 5 are a part of the Clarion-Nicollet-Webster soil association (Blanchet, 1996; Chinkuyu et al., 2002; Chinkuyu, 2000). These soils were derived from glacial till laid down during the last glacial retreat that extended throughout an area of Iowa known as the Des Moines lobe advance (SSD, no date; Chinkuyu et al., 2002; Chinkuyu, 2000) [Figure 5.2]. Originally, these soils yielded prairie vegetation before being converted to productive farmland (Chinkuyu et al., 2002; Chinkuyu, 2000) [More information about Field 5 soils can be obtained in Appendix A.].

Within field 5 are the eleven field plots that were used in this experiment. The field plots, as shown in Figure 5.3, vary in size from 0.19 ha (0.47 ac) to 0.42 ha (1.04 ac). These field plots were established in 1984 and each is drained by a single subsurface tile drain

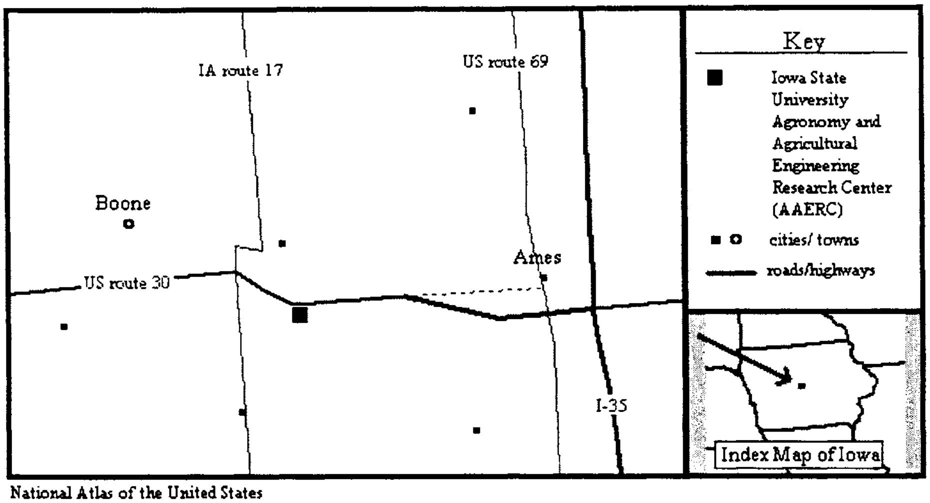


Figure 5.1 Location of Agronomy and Ag. Engineering Research Farm in relation to Ames, and Boone.

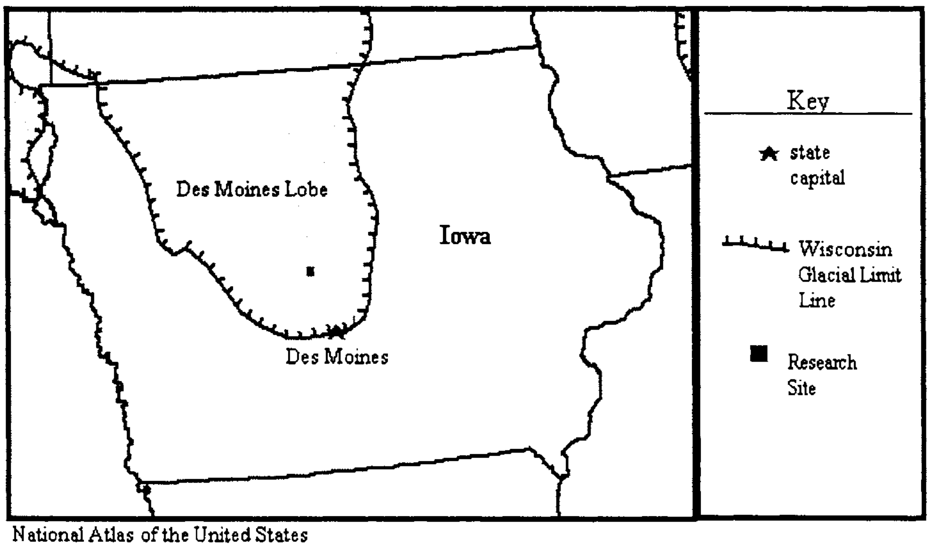
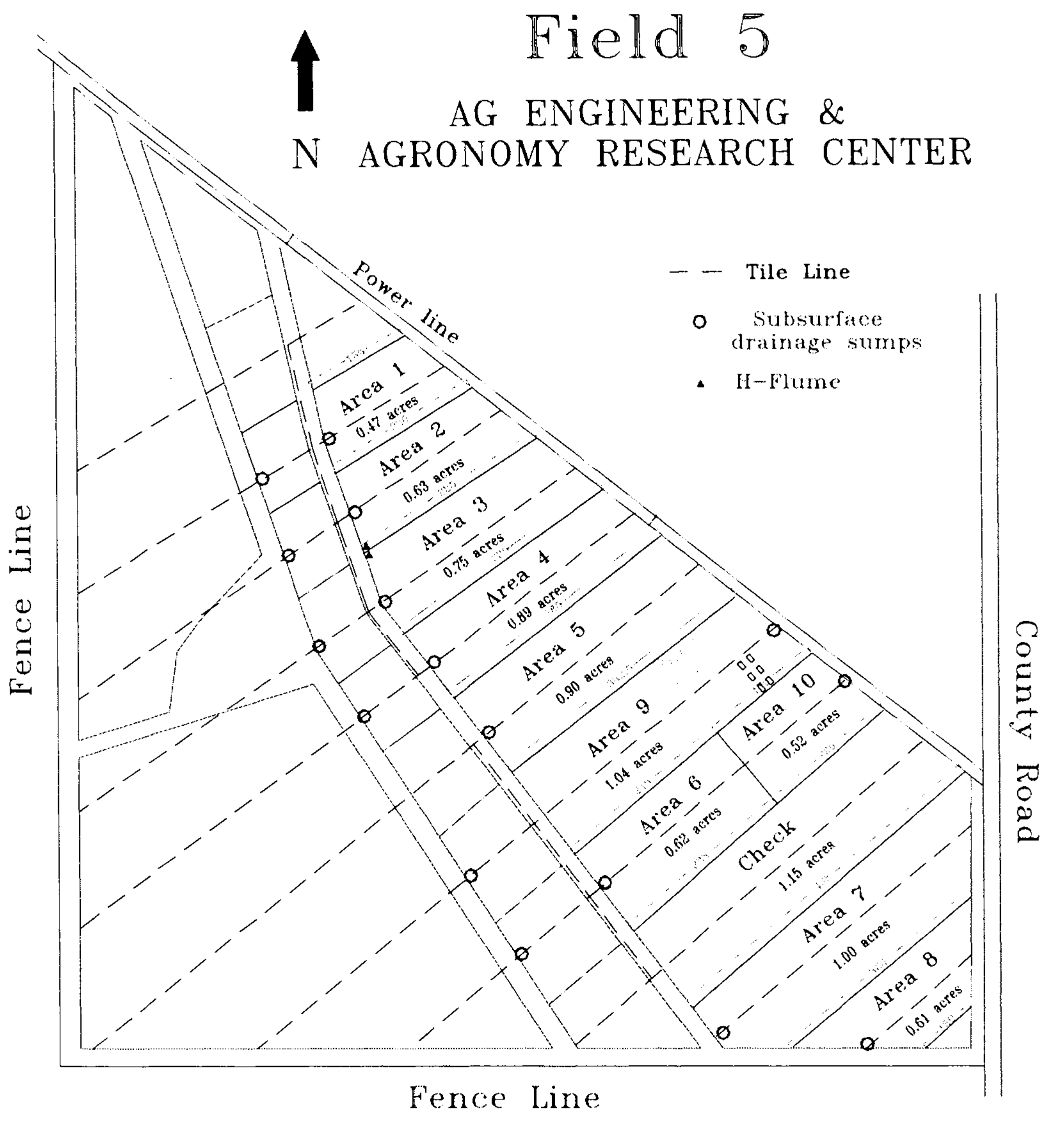


Figure 5.2. Extent Des Moines Lobe Glacial Advance.



1 336 kg-N/ha Poultry Manure
2 168kg-N/ha Poultry Manure
3 336 kg-N/ha Poultry Manure
4 168 kg-N/ha UAN Fertilizer
5 168 kg-N/ha Poultry Manure
6 168 kg-N/ha UAN Fertilizer
7 336 kg-N/ha Poultry Manure
8 168 kg-N/ha UAN Fertilizer
9 168 kg-N/ha UAN Fertilizer
10 168 kg-N/ha Poultry Manure
Check Plot : No Poultry Manure or UAN Fertilizer

Figure 5.3. Field Plots in Field 5.

that runs through the center of the plot and is intercepted by a sump containing monitoring devices for measuring water flow and collecting samples for water quality analysis (Kanwar et al., 1988; Blanchet, 1996). The sump for the control (check) plot was not installed until fall 1999.

Six lysimeters were also used for this study and are located within field plot 9 (Figure 5.4). Constructed in 1992, the lysimeters are arranged in two rows of three with each lysimeter being 381 cm (12.5 ft) apart from each other (Figure 5.5). First, the containers to hold the soil profiles were assembled. Each container consists of three layers: an outer polyethene plastic layer, a middle Styrofoam layer, and an inner plastic liner (Figure 5.6). Then, using a grave-digging machine, the soil profiles that would be used to fill the lysimeter containers, were removed in 15 and 30 cm deep layers, in such a way, that the profile could be reassembled when the soil would be put in the containers. Once the soil was removed, four soil core samples were taken from the walls in each of the four sides of the holes and tested for hydraulic conductivity, bulk density, and other soil properties, which are given in Blanchet (1996). Then a Bentonite (clay) layer was added to the bottom of the holes before the containers were lowered into them. Afterwards, more Bentonite was used to fill in the space between the lysimeter containers and the walls of the hole. Then, the sump and tile system was installed inside to the lysimeters before finally packing the soil layers into the lysimeters (Figure 5.6). Care was taken to reassemble the original soil profiles. More details on the construction and installation of the lysimeters are given in Blanchet (1996).

Experimental Treatments: Manure/Fertilizer Applications

Laying hen poultry manure used in this experiment was obtained from a laying hen farm located in Humboldt, Iowa. Prior to applying the poultry manure to the field plots and

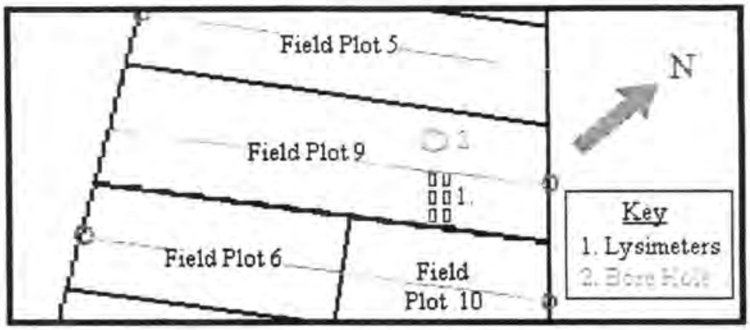


Figure 5.4. Location of Lysimeters.

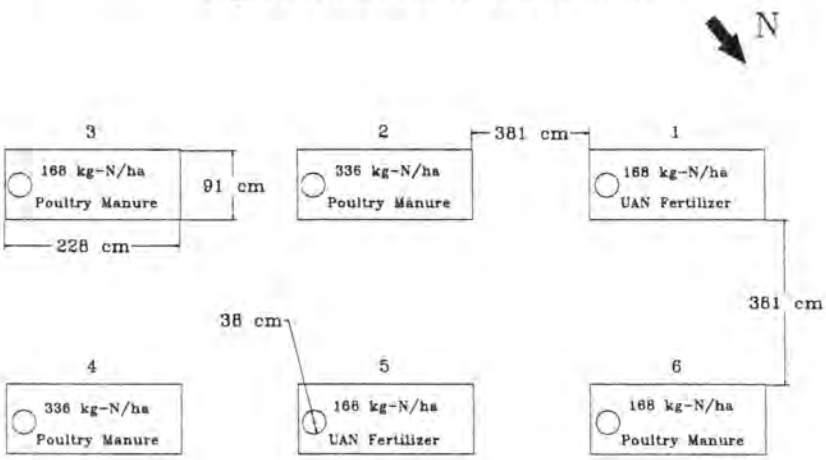


Figure 5.5. Layout of lysimeters to study the effects of N management systems on subsurface drainage water quality.

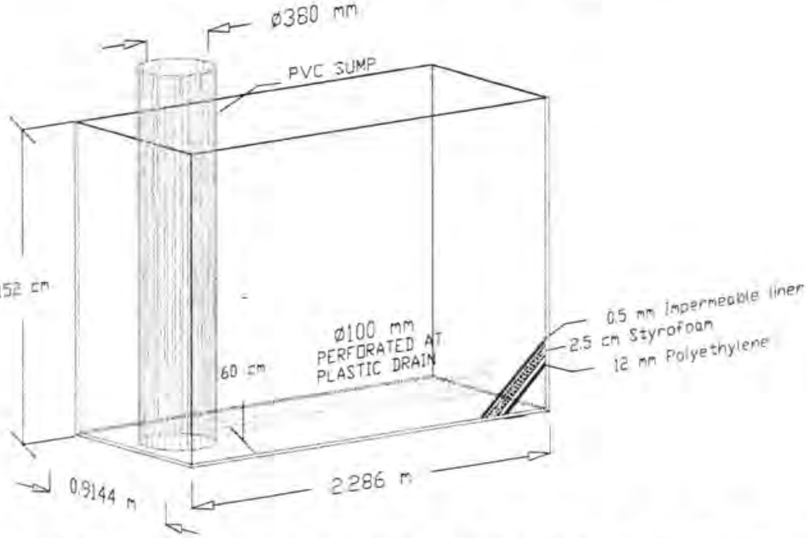


Figure 5.6. Design details of lysimeter construction box to study the effects of N management systems on subsurface drainage water quality.

lysimeters, samples of the manure were taken and sent to MVTL Laboratories, Inc., located in Nevada, Iowa, to test for total moisture, total nitrogen, phosphorus, potassium, and ammonia-nitrogen. Results from the analysis are given in Table 5.3.

Field Plot. The following treatments were applied on the field plots: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), *iii*) 336 kg N/ha from poultry manure (PM2), and *iv*) 0 kg N/ha (control treatment). These treatments were randomly assigned to each field plot, but due to the number of field plots available, the treatments were unbalanced with the UAN treatment having four replicates, PM treatment having three replicates, the PM2 treatment having three treatments, and the control treatment having one replicate. Figure 5.3 shows which field plots received what treatment.

The manure was applied to the field plots by surface broadcast on one half of the plots, which are planted in corn. The other half of each field plot that was planted to soybeans received no manure or N fertilizer. After manure or UAN fertilizer was applied to the field plots, it was incorporated into the soil that day or the day after by tilling/disking the soil down to a depth of about 15 cm (6 inches). This was done to help minimize N losses through volatilization (Chinkuyu et al., 2002; Chinkuyu, 2000).

Lysimeters. The following treatments were applied on the lysimeters: *i*) 168 kg N/ha from urea ammonium nitrate (UAN), *ii*) 168 kg N/ha from poultry manure (PM), and *iii*) 336 kg N/ha from poultry manure (PM2). The treatments were randomly assigned to the lysimeters, giving a total of two replicates per treatment as listed in Figure 5.5. A control treatment was not used for the lysimeters due to the number of lysimeters available for this study (Chinkuyu et al., 2002).

Table 5.3. Characteristics of poultry manure applied to field plots and lysimeters.

Characteristics	1998	1999	2000	2001	2002	2003
Field Plots						
	168 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.49	3.04	2.69	2.16	1.41	2.03
Ammonia (NH_3), %N	1.00	4.37	3.94	2.72	2.24	1.60
Total Phosphorus, %P	1.43	2.29	2.41	20.62	1.20	1.81
Potassium, %K	1.11	0.74	0.72	8.50	0.57	1.71
Moisture Content, %H_2O	48.12	45.03	32.60	56.97	53.70	76.25
	336 kg N/ha Poultry Manure Treatment					
Total Kjedhal N (TKN), % N	1.51	2.98	3.73	2.16	1.41	2.03
Ammonia (NH_3), %N	0.94	4.21	3.76	2.72	2.24	1.60
Total Phosphorus, %P	1.25	1.86	2.25	20.62	1.20	1.81
Potassium, %K	1.06	0.82	0.78	8.50	0.57	1.71
Moisture Content, %H_2O	46.88	54.60	32.23	56.97	53.70	76.25
Lysimeters						
	168 kg N/ha and 336 kg N/ha Poultry Manure Treatments					
Total Kjedhal N (TKN), % N	1.49	2.98	3.80	6.08	1.06	2.03
Ammonia (NH_3), %N	1.00	4.21	3.73	2.10	3.29	1.60
Total Phosphorus, %P	1.43	1.86	2.37	1.28	1.43	1.81
Potassium, %K	1.11	0.82	0.66	1.32	0.45	1.71
Moisture Content, %H_2O	48.00	55.00	27.90	56.90	58.20	76.25

*Conversion for nutrients: % *20 = lbs/ton

The manure or UAN fertilizer was applied to the lysimeters by hand. First a shovel was used to break up the soil in each lysimeter bed. Then, using a portable balance, the proper amount of manure/fertilizer was weighted on the bases of nitrogen content of the manure/fertilizer being used in a given year. Manure/fertilizer was spread over the surface of each lysimeter, and using the shovel was incorporated into the soil that same day (Chinkuyu et al., 2002). Even though the intended application rates applied to both field plots and lysimeters were based on the nitrogen treatments UAN, PM, and PM2, "the actual amounts of N applied to the plots and lysimeters were different from the desired N application rates because the N content in the manure (determined at the beginning) used in the calibration of the manure spreader was different from the N content determined at the time of application" (Chinkuyu et al., 2002; Chinkuyu, 2000). The actual N application rates for the two treatments averaged: *i*) PM = 170 kg N/ha and *ii*) PM2 = 321 kg N/ha for the field plots and *i*) PM = 254 kg N/ha and *ii*) PM2 = 508 kg N/ha for the lysimeters as shown in Table 5.4.

Planting

The field plots were planted to a corn-soybean rotation in such a way that both corn and soybeans are planted on the same field plot in the same year. Using the center tile drain in the middle of each field as a dividing line, one half of the field plot was planted to corn and the other half was planted to soybeans. In even years, like 1998, corn was planted on the northern half of the fields and soybeans on the southern half. Then in the following year (an odd year, like 1999), corn was planted on the southern half of the fields and the soybeans on the northern half. The corn variety Dekalb 580 and soybean variety Kruger 2426 were used in the experiment with each being planted at a spacing of 0.75 m between rows and 0.2 m between plants within each row (Chinkuyu et al., 2002; Chinkuyu, 2000).

Table 5.4. Average manure application rates for field plots and lysimeters (1998-2003).

	168 kg N/ha poultry manure				336 kg N/ha poultry manure			
	Average manure application rate, kg/ha	Average application rate, kg/ha*			Average manure application rate, kg/ha	Average application rate, kg/ha*		
		N	P	K		N	P	K
Field Plots								
1998	10674	159	107	152	24190	364	227	303
1999	9575	291	418	220	14774	440	622	275
2000	3213	86	126	78	8741	326	329	196
2001	8998	195	244	1855	14957	324	406	3083
2002	7982	113	179	96	14295	202	320	172
2003	11318	229	181	205	18231	369	292	330
6-yr average	8627	179	209	434	15865	337	366	727
Lysimeter								
1998	15717	234	157	225	31720	473	317	454
1999	2902	86	122	54	5804	173	244	108
2000	2190	83	82	52	4379	166	163	104
2001	10189	620	214	130	20378	1239	428	261
2002	9182	97	302	131	18382	195	605	263
2003	9179	186	147	166	18359	372	294	333
6-yr average	8226	218	171	126	16504	436	342	254

* Assumed 5% N, P, and K lost during application; 75% N, P, and K available during the first year. In subsequent years no credit was given for residual N, P, and K from the manure or N from soybeans.

¶ Intended N application rates from layer manure were 168 kg-N/ha and 336 kg-N/ha, however, actual N application rates averaged PM = 179 kg-N/ha and PM2 = 337 kg-N/ha for the plots; PM = 218 kg-N/ha and PM2 = 436 kg-N/ha for the lysimeters.

The lysimeters were planted to continuous corn using Dekalb 580 corn variety. Twelve corn seeds were evenly planted in each lysimeter bed in three rows of four (0.75 m between rows and 0.2 m between plants within each row) (Chinkuyu et al., 2002; Chinkuyu, 2000). If the planted corn seeds did not grow or field rodents ate the seeds, corn plants from the adjacent field plot were dug up and transplanted into the lysimeter beds in order to maintain a population of twelve plants in each lysimeter.

Methods used in the harvesting and grain quality analysis for field plots and lysimeters are given in Chapter 2 of this thesis.

Tillage

Once the field plots had been harvested, the side of each field plot that had corn for that year was tilled using a chisel plow which allows about 30% of the crop residue to remain on the surface of the soil. The side of each field plot that was planted in soybeans did not receive the fall tillage.

Bacteria

Bacteria samples were taken in order to estimate the probability of fecal contamination in water sources. The bacteria themselves are known as indicator bacteria because they are thought to indicate the possible presence of pathogenic bacteria and viruses, which could potentially end up in the water sources that receive fecal matter contamination. The water quality standards used for bacteria contamination, when testing water in Iowa based on intended use, are given Table 5.5.

Field Plot Sampling. A grab sample of subsurface tile drain water was collected using Whirl-pak bags and labeled. Then these water samples were stored in a cooler at 4 degrees C and were tested within twenty-four hours of samples collection.

Table 5.5 Maximum Allowable Colony Counts for Different Types of Water based on Usage.

Type of Water	Total Coliform/100 mL	Fecal Coliform/100 mL	Fecal Streptococcus/100 mL	E. coli/100 mL
Drinking water (Class C)	0	0	0	0
Primary Contact (swimming) (Class A)	<1000	<200	33	126
Secondary Contact (boating, fishing) (Class B)	<5000	<1000	165	630

*Millipore booklet

*Iowa DNR http://www.state.ia.us/government/dnr/beach2000.htm

*EPA ambient water quality handbook (1986).

Lysimeter Sampling. During the pumping of subsurface drainage water from each lysimeter, a grab sample was taken using a whirl pak bag, labeled, and stored in a 4 degree C cooler until they are tested within twenty-four hours of its collection.

Testing

Total Coliform and *Escherichia coli* (*E. coli*). The membrane filtration method of enumeration was used to for total coliform and E. coli. First, the water samples were removed from the cooler and a filtration apparatus was set up. Liquid medium cassette petre dishes were prepared using m-ColiBlue24 broth. Using the filtration apparatus, the water samples were filtered and the filter paper was applied to the medium plates. Each water sample had 1 to 3 of four dilutions run on it (100 mL, 50 mL, 10 mL, or 1 mL). Once the cassette dishes were prepared, they were set lid side down in an incubator for 24 hours at 35+/- 0.5 degrees C. After the 24 hours, the cassette dishes were removed from the incubator and the number of total coliform and E. coli colonies were counted. The E. coli colonies appeared blue and the other coliform bacteria present appeared red (E.coli is a type of total coliform so it is added to the number of other coliforms present). When the number of colonies on a cassette exceeded 200, the number of colonies was recorded as TNTC (too numerous to count). Finally, the raw numbers were converted to colony forming units per 100 mL (CFU/100 mL) by using the formula listed in below.

No. of indicator organism/ 100 mL = No. of colonies counted * 100/mL of sample

(Millipore, 1992.)

Fecal Coliform. The membrane filtration method of enumeration was used to test for fecal coliform, the water samples were removed from the cooler and a filtration apparatus was set up. Liquid medium cassette petre dishes were prepared using m-FC Broth with rosolic acid. Using the filtration apparatus, the water samples were filtered and the filter paper was applied to the medium plates. Each water sample had 1 to 3 of four dilutions run on it (100 mL, 50 mL, 10 mL, or 1 mL). Once the cassette dishes were prepared, they were set lid side down in an incubator for 24 hours at 44.5 ± 0.2 degrees C. After the 24 hours, the cassette dishes were removed from the incubator and the number of fecal coliform colonies were counted. The fecal coliform colonies appeared blue and any other type of bacteria appeared cream to gray in color. When the number of colonies on a cassette exceeded 200, the number of colonies was recorded as TNTC (too numerous to count). Finally, the raw numbers were converted to colony forming units per 100 mL (CFU/100 mL) by using the formula given earlier.

Fecal Streptococcus. The membrane filtration method of enumeration was used to test for fecal streptococcus, the water samples were removed from the cooler and a filtration apparatus was set up. Pre-filled medium cassette petre dishes were used containing KF Strep Agar. Using the filtration apparatus, the water samples were filtered and the filter paper was applied to the medium plates. Each water sample had 1 to 3 of four dilutions run on it (100mL, 50 mL, 10 mL, or 1 mL). The cassette dishes were then set lid side down in an incubator for 48 hours at 34-36 degrees C. After the 48 hours, the cassette dishes were removed from the incubator and the number of fecal coliform colonies were counted. The fecal coliform colonies appeared pink to red in color. If the number of colonies on a cassette exceeded 200, it was recorded as TNTC (too numerous to count). Finally, the raw numbers were converted to colony forming units per 100 mL (CFU/100 mL) by using the formula given earlier.

Results and Discussion

Statistics

The data collected in this study on bacteria concentrations in water were analyzed using a split-plot model using SAS version 8.2. First the data were tested using an F test. If the results indicated that there were significant differences in the treatment results, then a student t-test were conducted to indicate the significance between treatments. All tests were done using an alpha value of 0.05. For field plots, the bacteria concentrations in the subsurface drainage water of the control treatment was left out of the statistical analysis because only one replication for the control treatment was available and all six years data were not available. For field plot bacteria concentrations in runoff water, no statistical analysis was conducted because of lack of replications for each of the treatments.

Effects of Poultry Manure on Total Coliform Concentrations in Subsurface Drainage and Surface Runoff Water

Subsurface Drainage. The six-year averages for total coliform concentrations in subsurface drain water from field plots are given in Table 5.6. The data in Table 5.6 shows that bacteria concentrations were all below the limit (>1000 CFU/100 mL) for primary contact waters. Total coliform counts from PM2 treatment were the highest in comparison with the UAN, PM, and control treatments (Table 5.6).

The total coliform concentrations in subsurface drain water from the lysimeters are given in Table 5.7. The bacteria concentrations from lysimeter drain water were below the primary contact water limit of >1000 CFU/100 mL. Total coliform concentrations in the drain water from the PM and PM2 treatment effects were higher in comparison with the UAN treatment effects.

Fecal Coliform

Subsurface Drainage. The six-year average fecal coliform bacteria concentrations in subsurface drain water from field plots are given in Table 5.6. Fecal coliform counts in the subsurface drain water from PM2 treatment plots were higher in comparison with the UAN and PM treatments. In addition, PM2 treatment resulted in fecal coliform concentrations that exceeded the primary contact water limit of >200 CFU/100 mL. Also, lysimeter fecal coliform bacteria concentrations are given in Table 5.7. These results show that fecal coliform counts from PM and PM2 treatment effects were significantly higher compared in comparison to UAN treatment. The fecal coliform counts in the subsurface drain water from the PM and PM2 treatments exceeded the primary contact water limit of >200 CFU/100 mL while counts from the UAN treatment were lower. Both poultry manure treatment results in higher fecal coliform concentrations in drain water in comparison to the 168 kg-N/ha UAN treatment, and these concentrations exceeded the primary contact water limit of >200 CFU/100 mL.

Table 5.6. Bacteria concentrations (CFU/100 mL) in field plot subsurface drain and surface runoff water (1998-2003).

Year	Subsurface Tile Flow				Runoff Flow	
	Check[#]	UAN	PM	PM2	PM	PM2
Total Coliform	---‡	---	---	---	---	---
1998	---	---	---	---	---	---
1999	---	---	---	---	---	---
2000	---	---	---	---	---	---
2001	233	85a*	250a	400a	---	---
2002	303	1157b	661b	2409a	---	---
2003	159	189a	255a	229a	---	---
5-yr average	232	477a	393a	10130a	---	---
Fecal Coliform						
1998	---	12a	9a	203a	---	---
1999	---	123a	182a	291a	509	744
2000	80	101a	59a	370a	---	1000
2001	---	---	---	---	---	---
2002	---	---	---	---	---	---
2003	---	---	---	---	---	---
5-yr average	80	78a	83a	288a	509	772
E. coli						
1998	---	4b	28b	266a	---	---
1999	---	34a	69a	70a	451	357
2000	25	60a	59a	80a	25	500
2001	20	0b	2b	110a	---	---
2002	12	13a	9a	16a	---	---
2003	0	0a	0a	0a	---	---
5-yr average	14	19a	27a	90a	238	428
Fecal Strept						
1998	---	44a	61a	234a	---	---
1999	---	114a	126a	240a	663	1097
2000	64	74a	19a	158a	200	1315
2001	---	---	---	---	---	---
2002	---	---	---	---	---	---
2003	---	---	---	---	---	---
5-yr average	64	77a	69a	210a	431	1206

[#] CHECK: 0kg-N/ha; UAN: 168 kg-N/ha from UAN fertilizer; PM: 168 kg-N/ha from poultry manure; PM2: 336 kg-N/ha from poultry manure. * Values in the same row followed by the same letter, in each experiment, are not significantly different at significance level of P = 0.05. ‡ - no data.

Table 5.7. Bacteria concentrations (CFU/100 mL) in lysimeter subsurface drain water (1998-2003).

Year	Subsurface Tile Flow		
	UAN#	PM	PM2
Total Coliform			
1998	521a*	614a	568a
1999	---‡	---	---
2000	---	---	---
2001	133b	104b	559a
2002	370b	416a	969a
2003	608b	664b	262a
6-yr average	408a	450a	590a
Fecal Coliform			
1998	64a	10a	113a
1999	197a	198a	282a
2000	0a	423b	221ab
2001	---	---	---
2002	---	---	---
2003	---	---	---
6-yr average	32a	210a	205a
E. coli			
1998	36b	146b	501a
1999	99a	103a	78a
2000	33a	16a	206a
2001	0a	2a	0a
2002	1a	1a	0a
2003	5a	0a	4a
6-yr average	29b	44b	131a
Fecal Strept			
1998	379a	144a	362a
1999	290a	278a	244a
2000	187a	106a	98a
2001	---	---	---
2002	---	---	---
2003	---	---	---
6-yr average	285a	176a	235a

UAN: 168 kg-N/ha from UAN fertilizer; PM: 168 kg-N/ha from poultry manure; PM2: 336 kg-N/ha from poultry manure. * Values in the same row followed by the same letter, in each experiment, are not significantly different at significance level of P = 0.05. ‡ - no data.

Runoff Water. The fecal coliform concentrations in the runoff water are from field plots given in Table 5.6. The fecal coliform counts in the runoff water from PM2 treatment were higher in comparison with the PM treatment. Fecal coliform counts in runoff water from both PM and PM2 treatments exceeded the primary contact water limit of >200 CFU/100 mL but these concentrations were under the limit for secondary contact waters.

E. coli

Subsurface Drainage. The E. coli bacteria concentrations in subsurface drain water from field plots are given Table 5.6. The data in Table 5.6 show that E.coli counts from PM2 treatment were significantly higher in comparison with E.coli counts from PM and UAN treatment. E.coli counts from all treatments were below the primary contact water limit of 200 CFU/100 mL.

The E.coli bacteria concentrations in subsurface drain water from lysimeters are given in Table 5.7. The E.coli counts from the PM2 treatment were significantly higher than E.coli counts from the UAN and PM treatments.

Runoff Water. The E.coli bacteria concentrations in runoff water from field plots are given in Table 5.6. Again, the E.coli counts in the runoff water from the PM2 treatment were higher compared to E.coli counts from the PM treatment.

Fecal streptococcus

Subsurface Drainage. The fecal streptococcus bacteria in subsurface drain water from field plots are given in Table 5.6. The fecal streptococcus counts from the PM2 treatment were higher in comparison with the PM and UAN treatments. In addition, the PM2 treatment exceeded both the primary and secondary contact water limits of 33 and 165 CFU/100 mL in water, respectively.

The fecal streptococcus bacteria concentrations in the subsurface drain water from the lysimeters are given in Table 5.7. Fecal streptococcus counts from PM treatments were lower in comparison with the fecal streptococcus counts from the UAN and PM2 treatment. The fecal streptococcus concentrations from poultry manure treatments exceeded the secondary contact waters limit of 165 CFU/100 mL.

Runoff Water. The fecal streptococcus concentrations in runoff water from field plots are given in Table 5.6. Fecal streptococcus counts from both the PM and PM2 treatments exceeded both the primary and secondary contact limits.

Summary and Conclusions

This study resulted in the following conclusions:

i) Bacteria concentrations in subsurface and runoff water from the PM2 treatment were higher in comparison with the UAN and PM treatments.

ii) Bacteria concentrations from the PM2 treatment were double in comparison with bacteria concentrations from the PM treatment.

iii) The overall results of this study indicate that the PM treatment is the better choice for applying plant nutrients to fields because of lower concentrations of bacteria in subsurface drain water and surface runoff water. As long as the poultry manure is applied at the reasonable nitrogen rates of 168 kg-N/ha, it will give better crop yields in comparison with the UAN treatment and will result in lower bacteria concentrations in subsurface drainage and runoff waters in comparison with the PM2 treatment.

References

Beyer, Scott R. Revised 2002. *Frequently Asked Questions About Poultry.* Kansas State University Research and Extension. Publication not numbered. http://www.oznet.ksu.edu/poultry/faq.htm#E.%20Layers (Date accessed: November 19, 2003)

Blackmer, A.M. and A.P. Mallarino. Sept. 2000. "Cornstalk testing to evaluate nitrogen management." Department of Agronomy, Iowa State University. http://www.extension.iastate.edu/Publications/PM1584.pdf (Date accessed: November 19, 2003)

Blanchet, L. 1996. Impact of lime application on transport of nitrate-nitrogen, atrazine, and cyanazine to subsurface drainage water: A lysimeter study. MS thesis. Ames, Iowa: Iowa State University.

Chinkuyu, Adion. 2000. Environmental impacts of the use of poultry manure for agricultural production systems. PhD dissertation. Ames, Iowa: Iowa State University.

Chinkuyu, Adion, R.S. Kanwar, J.C. Lorimor, H. Xin, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. Transactions of the ASAE 45(2): 299-308.

Kanwar, R.S., J.L. Baker, and D.G. Baker. 1988. Tillage and split N-fertilization effects on subsurface drainage water quality and crop yields. Trans. ASAE 31(2): 453-461.

Klapper, Betty, H. M. Taybor, M. G. Huck, and E. L. Fiscus. 1973. Water relations and growth of cotton in drying soil. Agronomy Journal. Vol 65: 307-310.

Millipore. 1992. Water Microbiology Laboratory and Field Procedures. Bedford, Massachusetts.

National Atlas of the United States, December 8, 2000, http://nationalatlas.gov (Date accessed: November 19, 2003)

Schwantz, Lee. 1979. "Feeding Instructions." Farmer's Digest. Wisconsin. (Referenced from *The Family Poultry Flock*) Website: *CHICKEN FEED: The* World of Chickens http://www.lionsgrip.com/feedinstruc.html (Date accessed: November 19, 2003)

Soil Conservation Service. 1992. National Engineering Handbook: Agricultural Waste Management Field Handbook. United States Department of Agriculture.

Soil Survey Division (SSD), Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. http://ortho.ftw.nrcs.usda.gov/osd/ (Date accessed: January 3, 2003).

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 1999. Agricultural Statistics 1999. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2000. Agricultural Statistics 2000. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2001. Agricultural Statistics 2001. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2002. Agricultural Statistics 2002. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2003. Agricultural Statistics 2003. www.usda.go/nass/pubs/agstats.htm (Date accessed: November 19, 2003)

U.S. Environmental Protection Agency (EPA). Jan. 1986. *Ambient Water Quality Criteria for Bacteria-1986.* U.S. Environmental Protection Agency, Office of Water (4305T), 1200 Pennsylvania Ave., NW, Washington D.C. 20460. Publication EPA-440-5-84-002. http://www.epa.gov/ost/standards/bacteria/ (Date Accessed: November 21, 2003)

U.S. Environmental Protection Agency (EPA). May 2002 (Draft). *Implementation Guidance for Ambient Water Quality Criteria for Bacteria.* U.S. Environmental Protection Agency, Office of Water (4305T), 1200 Pennsylvania Ave., NW, Washington D.C. 20460. Publication EPA-823-B-02-003. http://www.epa.gov/ost/standards/bacteria/ (Date Accessed: November 21, 2003)

U.S. Geological Survey, October 2002, Cities and Towns, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, November 2002, Aquifers of Alluvial and Glacial Origin, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, January 2002, Roads, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

U.S. Geological Survey, July 2002, States, *in* National Atlas of the United States, http://nationalatlas.gov. (Date accessed: November 19, 2003)

CHAPTER 6: GENERAL CONCLUSIONS

General Discussion

The objective of this research was to understand how poultry manure, applied to fields, impacts subsurface drain water and surface runoff water quality. Specific objectives that were investigated in this study were:

1. To determine how different rates of poultry manure effect crop yields, grain quality, and plant stalk nitrogen uptake in comparison to using a commercial fertilizer.
2. To determine how different rates of poultry manure effect NO_3-N and PO_4-P nutrient concentrations in the soil over time in comparison to using a commercial fertilizer.
3. To determine how different rates of poultry manure effect NO_3-N and PO_4-P nutrient concentrations and losses in subsurface tile water and runoff water in comparison to using a commercial fertilizer.
4. To determine how different rates of poultry manure effect bacteria concentrations in subsurface tile and runoff water in comparison to using commercial fertilizer.

The yields produced by field plots under the 168 kg N/ha poultry manure (PM) were slightly higher than that from the 168 kg N/ha UAN (UAN) treatment even though statistically they were the same. The double rate poultry manure treatment was also showing high yields that were numerically higher than the PM and UAN treatments but statistically were similar.

Soil NO_3-N levels in the top 6 inches were higher in field plots under the UAN treatment than those under the PM treatment, and actually were almost equivalent to soil NO_3-N levels in field plots under the 336 kg N/ha poultry manure (PM2) treatment (double the single nitrogen rate using poultry manure). Soil PO_4-P levels are all relatively high in field plots under all treatments in the top 6 inches of the soil. Numerically, the poultry manure treatment effects were higher than that of the UAN and no nitrogen treatments. Over time, the PM2 treatment had increases in soil PO_4-P over time while the other treatments experienced no trends or declines in soil PO_4-P.

Even though many of the treatment averages were significantly similar, numerically the 168 kg N/ha poultry manure was causing less nutrient concentrations and losses in subsurface drainage and runoff water than UAN. Additionally the UAN treatment was causing nutrient losses equivalent to the double poultry manure treatment.

Bacteria concentrations for the PM treatment were about the same as that of the UAN treatment effects except in the case of the fecal streptococcus bacteria where the UAN treatment had higher concentrations. Also, the differences in poultry manure rates could be seen in the bacteria concentrations. More bacteria were present when the high rate poultry manure treatment was applied as compared to the single nitrogen rate poultry manure treatment.

Thus, it can be concluded that the PM treatment is the better choice in applying nutrients to fields because of high yields, which were significantly higher than the UAN treatment and similar to the higher rate PM2 treatment. In addition, the PM treatment resulted in reduced levels of soil NO_3-N levels compared to UAN treatment and lower soil PO_4-P trends compared to the PM2 treatment. Also, the PM treatment resulted in reduced NO_3-N losses in subsurface drainage water as compared to the UAN and PM2 treatments. Bacteria concentrations from PM2 treatment effects were higher compared to concentration effects from UAN and PM treatment effects. Also, there is a clearly higher bacteria concentration effects from the PM2 treatment compared to the PM treatment effects.

As long as the poultry manure is applied at reasonable nitrogen rates (of 168 kg N/ha), it makes a good soil amendment, gives better crop yields, and reduced NO_3-N concentrations in subsurface drain water compared to 168 kg N/ha from UAN and 336 kg N/ha from poultry manure.

Recommendations for the Future

The lysimeters may be more suited to observations that would take place in a smaller volume of soil. In the case of this study, the small volume may have hindered the crops from behaving as they would in a larger field setting. Specifically, the lysimeters in this experiment were self-contained in that no water other than that from rainfall could enter or leave the soil volume being tested. In a large field setting, water would drain down through the soil past the four-foot depth limit of the lysimeters during the spring rains and later could be draw up to the upper depths in the later summer time. This would allow the crops to obtain water throughout the growing season. Also, the crops could extend their roots down deeper to obtain available water, but since the lysimeters were in a container, the crops cannot go any deeper than the bottom of the container. This may have been what was effecting the lower yields observed in the lysimeters as compared to the field plots.

More replications of the treatments would make treatment averages more reliable, as well as, giving the statistical analysis more to go by in finding significant differences in treatment effects. Additionally, taking soil samples on the soybean side of the field plots would give a better picture of what was going on during years of no treatment application.

Possible research that could be looked at in the future is looking at poultry manure impacts based on phosphorus application rates as opposed to nitrogen rates since there has been a push toward applying manures according to the phosphorus needs of crops in order to reduce phosphorus build up in the soil. Another topic that can be looked at would be to see if crops that are tilled under after harvest are significantly contributing to the phosphorus needs of crops for the next growing season, as well as, whether this could have potential environmental impacts. A third topic that could be looked at would be to determine what the normal bacteria levels in Iowa soils are, for better monitoring of indicator organisms in soils, subsurface drainage waters, and runoff waters.

APPENDIX A

Section 1: Soil Taxonomy and Characteristics of Field 5 Soils

Soil Taxonomy of Harps, Webster, Canisteo, Nicollet, and Clarion Soils
[From: Soil Survey, 1998; U of Idaho, no date]

Mollisols (order) [grassland soils with high base status]

Aquolls (suborder)

Calciaquolls (great group)

Typic Calciaquolls (subgroup)

Harps

Endoaquolls (great group)

Typic Endoaquolls (subgroup)

Webster

Canisteo

Udolls (suborder)

Hapludolls (great group)

Aquic Hapludolls (subgroup)

Nicollet

Typic Hapludolls (subgroup)

Clarion

Table A.1 Soil series characteristics.

Soil Series	Taxonomy	General Character	Slope	Drainage/ Permeability	Vegetation/Use	Distribution	Established
Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls	Very deep soils that formed in calcareous loamy glacial till or in a mantle of loamy or silty sediments and underlying calcareous loamy glacial till. These soils are on glacial moraines. The Canisteo soils have concave to slightly convex slopes with gradient of 0 to 2 percent in shallow swales, flats and on rims of depressions. They formed in loamy glacial till or in a thin, silty mantle and loamy glacial till	Slopes range from 0 to 2 percent.	Poorly drained and very poorly drained; runoff is negligible to low. Permeability is moderate.	Mostly under cultivation; corn and soybeans are the principal crops. Native vegetation is wet-site community of the tall grass prairie.	Southern Minnesota, northern Iowa, and Illinois, and eastern South Dakota. Extensive.	Dodge County, Minnesota, 1959.
Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludolls	Very deep soils formed in glacial till on uplands. Clarion soils typically are on convex slopes in the relatively undissected, gently undulating to rolling Late Wisconsin till plain. The topography is hilly in some places. Slopes commonly are short and irregular with gradients typically from 2 to 5 percent but range from 1 to 9 percent. The soils formed in calcareous glacial till of the Des Moines Lobe advance.	Slopes range from 1 to 9 percent.	Moderately well drained. Surface runoff is medium. Permeability is moderate	Mostly under cultivation; corn, soybeans, small grain, and legume hay are major crops. Native vegetation is tall grass prairie	North-central Iowa and south-central Minnesota. Extensive.	Hamilton County, Iowa, 1917

MLRA 103 = Major land resource area 103, Central Iowa and Minnesota Till Prairies (SSD, 2003)

Table A.1. Soil series characteristics (continued)

Soil Series	Taxonomy	General Character	Slope	Drainage/ Permeability	Vegetation/Use	Distribution	Established
Harps	Fine-loamy, mixed, superactive, mesic Typic Calciaquolls	Very deep soils formed in glacial till or alluvium on uplands. Harps soils are on till plains or moraines on narrow rims or shorelines of depressions and on slight rises within poorly defined swales or flats, and in a few places in swales or poorly defined drainageways. Slope gradients are 0 to 3 percent. Harps soils formed in glacial till of Wisconsin age or in alluvium derived from till. Thickness of the parent material ranges from 4 feet to more than 20 feet.	Slope ranges from 0 to 3 percent	Poorly drained. Runoff is slow. Permeability is moderate.	Commonly used for cultivated crops when drained. Corn and soybeans are generally grown. Native vegetation is prairie grasses tolerant of wetness.	Primarily in MLRA-103. This soil is extensive	Webster County, Iowa, 1968
Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludolls	Very deep soils that formed in calcareous loamy glacial till on till plains and glacial moraines. These soils have moderate permeability. They are on till plains, ground moraines, and terminal moraines. Their slopes range from 0 to 5 percent. They formed in friable, calcareous loam and clay loam glacial till of Late Wisconsinan age.	Their slopes range from 0 to 5 percent	Somewhat poorly drained. Permeability is moderate. Runoff is low.	Mostly cultivated to corn and soybeans. Native vegetation is tall grass prairie.	MLRA-103. South-central Minnesota and north-central Iowa. This soil is extensive	Nicollet County, Minnesota, 1949

MLRA 103 = Major land resource area 103, Central Iowa and Minnesota Till Prairies (SSD, 2003)

Table A.1. Soil series characteristics (continued)

Soil Series	Taxonomy	General Character	Slope	Drainage/ Permeability	Vegetation/Use	Distribution	Established
Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquolls	Very deep soils formed in glacial till or local alluvium derived from till on uplands. Webster soils are on relatively undissected till plains of Wisconsin age. Slopes are nearly plane to slightly concave and range in gradient from 0 to 3 percent. Webster soils formed in loamy glacial till of mixed mineralogy and from local alluvium from such till.	Slope ranges from 0 to 3 percent.	Webster soils are poorly drained, and most areas are artificially drained with tile and open ditches. Runoff is slow. Permeability is moderate.	Largely cultivated and cropped intensively to corn and soybeans. Small grain and hay are other major crops. Native vegetation is predominantly wet-site tall prairie grasses	North-central and central Iowa and south-central Minnesota. Extensive in MLRA-103.	Clay County, Iowa, 1916.

MLRA 103 = Major land resource area 103, Central Iowa and Minnesota Till Prairies (SSD, 2003)

Section 2: References

Soil Survey. 1998. 8th Edition. Keys to Soil Taxonomy. United States Department of Agriculture Natural Resources Conservation Serves.

Soil Survey Division (SSD), Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: http://ortho.ftw.nrcs.usda.gov/osd/ (Date accessed: January 3, 2003)

APPENDIX B

Section 1: Field Activities

Table B.1. Field activities in field plots and lysimeters from 1998 through 2003.

Field Activities	1998	1999	2000	2001	2002	2003
Field Plots						
Fertilizer/manure application	1-May	4-May	13-Apr	17-May	3-May	*
Incorporating manure	1-May	4-May	13-Apr	17-May	3-May	*
Planting corn	8-May	10-May	8-May	18-May	9-May	*
Planting soybean	8-May	10-May	8-May	18-May	22-May	*
Cultivating in corn plots	23-Jun	16-Jun	13-Jun	21-Jun	20-Jun	2-Jul
Cultivating in soybean plots	9-Jul	28-Jun	13-Jun	19-Jun	25-Jun	2-Jul
Harvesting soybeans	Sept. 28	Oct. 12	Sept. 20	Oct. 17	Oct. 15	*
Harvesting corn	Oct. 19	Oct. 14	Sept. 20	Oct. 15	Oct. 18	*
Cutting stalks	Oct. 25	Oct. 18	---	Nov. 19	---	*
Chisel plowing/primary tillage	Nov. 6	Nov. 12	---	Nov. 19	---	*
Lysimeters						
Fertilizer/manure application	20-May	5-May	14-Apr	25-Jun	22-May	29-May
Incorporating manure	20-May	5-May	14-Apr	25-Jun	22-May	29-May
Planting corn	21-May	10-May	8-May	25-Jun	22-May	29-May
Cultivating in corn plots	20-Jun	29-Jun	13-Jun	---	---	10-Jul
Harvesting corn	Oct. 5	Oct. 12	Sept. 21	Oct. 18	Oct. 15	*
Cutting stalks	---	---	---	Oct. 18	Oct. 15	*
Chisel plowing/primary tillage	20-May	5-May	---	---	---	*

* = Information being gathered, --- = No data.

Section 2: Laboratory Procedures

Corn Stalk N Analysis

When the lab receives corn stalk samples, they are first put in a drying unit to remove as much moisture from the stalks as possible. The dryer may be set as high as 140 degrees but depending on how green the stalks were when the lab received them, the stalks may take up to a week to dry. Once the corn stalks are thoroughly dried, they are ground down and then stored in sample bags until they can be tested. When the corn stalk samples are ready to be tested a sample size of ground corn stalk will be measured out. Depending on the lab doing the testing, the sample may be measured using a scoop of particular size (most common method) or the sample may be weighed out for bulk density. Once the sample has been measured, an extraction solution like ammonium acetate K or some other similar solution will be added to the ground corn stalk. The mixture is shaken and allowed to set for so many minutes before the mixture is filtered to remove the ground corn stalk material. The solution is then finally run in a spectrophotometer to determine the amount of NO_3-N present.

Soil Testing Procedure

When the lab receives the soil samples, they may be stored first before being put in a drying unit to remove as much moisture from the soil as possible. The dryer may be set at 100 degrees F or less. Once the soil is thoroughly dried, it is ground down to an even consistency and then stored in sample bags until it are tested. When the soil is ready to be tested a sample size of soil will be measured out. Depending on the lab doing the testing, the sample may be measured using a scoop of a particular size (which is the most common method) or the sample may be weighed out for bulk density. In this case two different samples will be measured out (one to test for NO_3-N and one to test for PO_4-P). Once the samples have been measured, a NO_3-N extraction solution will be added to the soil samples to be tested for NO_3-N and a PO_4-P extraction solution will be added to the other soil samples to be tested for PO_4-P. The mixtures are shaken and allowed to set for so many minutes before the mixtures are filtered to remove the soil material. Then the extraction solutions are finally run in a spectrophotometer at various wavelengths to determine the amount of NO_3-N and PO_4-P present.

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